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NRL Memorandum Report 754

SUMMARY OF NAVY STUDY PROGRAM FOR F4H-1 WEAPON SYSTEM

[UNCLASSIFIED TITLE]

VOLUME X1

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RADAR DIVISION

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August 1960

U. S. NAVAL RESEARCH LABORATORY
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NRL MEMORANDUM REPORT 754

SUMMARY OF NAVY STUDY PROGRAM FOR F4H-1 WEAPON SYSTEM

(Unclassified Title)

VOLUME XI

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AUGUST 1960

NAVY DEPARTMENT
NAVAL RESEARCH LABORATORY
RADAR DIVISION

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ABSTRACT
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The Naval Research Laboratory is serving as technical director of the Navy's Air to Air Missile Study. The results are presented in a series of volumes under NRL Memorandum Report 754. This volume is the eleventh in the series. The study to date has been primarily concerned with the system employing the F4H-1 aircraft, the AN/APQ-72 radar and the Sparrow III 6a missile. This volume presents study results accomplished prior to June 1960 and is a continuation of the study results detailed in preceding volumes.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem 53R05-04
BUWEPS No. RM 37-31-002/566-1/W102 BO-001

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SUMMARY OF NAVY STUDY PROGRAM FOR F4H-1 WEAPON SYSTEM

INTRODUCTION

The Bureau of Naval Weapons has contracted with the Naval Research Laboratory to conduct system studies directed toward establishing the tactical use capability of the Navy's Air to Air Missile Systems. These studies are conducted under the technical direction of the Naval Research Laboratory with all inputs derived from Navy sources. To date, study effort has been primarily directed toward revealing the tactical use capability of the F4H-1 Weapon System. In support of this effort, NRL has contracted with Westinghouse Air Arm Division for analytical services. Recommendations and conclusions to be drawn from analytical results are a Navy responsibility, and in particular, the responsibility of the technical director (NRL). This report is the eleventh in a series directed toward revealing the tactical effectiveness of the F4H-1 Weapon System.

The Navy study has been and will continue to be a cooperative effort. Wherever possible duplication has been avoided. Input data for the study has been obtained from the government facilities which most logically would cover the particular field. For example, radar test data was obtained from NATC; Sidewinder performance data was obtained from NOTS; and Sparrow III seeker performance data was obtained from NMC. In addition, the facilities of the various activities have been, in effect, pooled so that special talents and equipments can be employed. The results of NMC simulator studies to ascertain the allowable launch error for Sparrow III, and the effects of hydraulic oil limits, have been incorporated in the overall study. In addition, NMC has conducted tests to verify the vectoring accuracies and to determine if the field degradation applied to AI radar detection range in this study is valid. It is very important that everyone concerned recognize that a study such as this must be a team effort. It is just as important to continue this team effort on future studies under the Sparrow III 6b and Eagle programs.

The study results to date have been presented in Volumes I, II, III, IV, VII, VIII, IX and X of this series (Refs. 1 thru 8). The study effort covered by these volumes carries the system through to Sparrow III 6a missile launch. At this point it is assumed that if the initial aircraft heading errors can be reduced to an acceptable launch error, the missile will fly perfectly to impact with the target. The probability of arrival to missile launch results presented in these preceding volumes are based upon this assumption.

The study effort covered by this and succeeding volumes is primarily concerned with the launch and missile guidance phases of the attack. The investigation of these phases of the attack has been divided into three parts and will be reported on in the same fashion. These three parts are:

1. Investigation of the tactical effectiveness of the F4H-1 weapon system when employing the Sparrow III 6a missile as defined at the start of the Navy's study. This missile is referred to throughout the text as the unimproved Sparrow III 6a.

2. Investigation of the sensitivity of system performance to Sparrow III 6a parameter variations.

3. Investigation of the tactical effectiveness of the F4H-1 system when employing the Sparrow III 6a missile as defined today. This missile will be referred to as the improved Sparrow III 6a.

This volume presents the results obtained under the investigation of Part I above. The other two phases will be detailed in succeeding volumes.

The material contained in this memorandum report is intended primarily for bureau information. As agreed during the contract negotiation, except for government activities, all distribution will be handled through bureau channels.

STUDY PROCEDURE

In preceding volumes the investigation of the tactical use capability of the F4H-1 Weapon System was restricted to those phases of the attack prior to missile launch. The interceptor aircraft (including pilot, radar operator, and displays), target, vectoring environment, and missile launching equations were simulated. Many possible tactical situations were examined. If the F4H-1 Weapon System arrived at a point within the allowable launch ranges and launch error, the missile was assumed to behave perfectly when launched. From the many situations examined, the probability of successful arrival to missile launch was developed for each type of attack. The study effort covered by this volume extends the work described in previous volumes to include missile launching and missile guidance to impact or miss at the target. The results presented previously form the basis for the input conditions of the launch and guidance investigation. Typical attack conditions are examined. The results are then presented in terms

of hit or miss at the target for each run examined. If a sufficient number of missile launch cases were examined, the probability of successful missile guidance could be developed. This probability could then be combined with the corresponding probability of successful arrival to missile launch. The result would be overall probability of success up to the point of fuzing. Unfortunately, time and funding do not permit such an extensive simulation. Only sample cases of missile launches can be examined.

INPUT DATA

With the exception of the unimproved Sparrow III 6a missile, the input conditions related to the subsystem performance and to the tactical situation have been detailed in preceding volumes. Only those items pertinent to the results presented in this volume will be repeated here.

Radar Analyses

The AI radar performance used in this phase of the study corresponds to that predicted for the AN/APQ-72 (XN-3). The 85% probability of detection range for this radar against a B-47 target flying at M 1.6 at 50,000 ft where $V_T/V_F = 0.8$ is shown in Fig. 1. Head-on, this radar has an 85% probability of detection at approximately 19 naut mi when the expected 10 db of field degradation is used. The radar has gimbal limits of ± 57° in azimuth and elevation. It is currently estimated that these gimbal limits will actually be ± 60°. This change has not been incorporated in the study to date.

Aircraft Analyses

The basic performance of the F4H-1 aircraft has been detailed in Volums I thru IV of this series. Changes in this performance have occurred during the study period covered by this report. However, these changes have not resulted in significant changes in system analyses results. Details of the performance changes which have occurred and which are now being used in the simulation program are given in Volume XII of this series (Ref. 11).

Missile Analyses

As stated above, this volume is primarily concerned with the launch and guidance phase of the attack. In preceding volumes much of the basic input data describing the missile has been given. These data, along with additional missile data pertinent to the simulation are given in Appendix I to this volume.

INVESTIGATION OF CO-ALTITUDE ATTACKS

This section of the report is restricted to the investigation of the missile launch and guidance phases of attacks made under co-altitude conditions. Throughout the tactical investigation associated with this phase of the report, the fighter speed at the beginning of the attacks was M 2.0 or V_{max}, and the target velocity used was M 2.0.

Initial Conditions

Although this report is primarily concerned with the missile launch and guidance phases of the attack, it is pertinent to review the method of simulation employed in all phases leading up to launch in order that the reader can get an understanding of the method of arriving at input conditions. The sequence of events leading up to missile launch has been investigated and the results described in preceding volumes. The F4H-1/AN APQ-72/AN APA-128 and pilot combination was simulated on a REAC-cockpit simulator at the beginning of the co-altitude study phase. Investigation of a large number of runs indicated that the mean of the REAC-cockpit simulator runs agreed with the results obtained from the IBM 704. In the actual investigation of co-altitude attacks under tactical conditions, the IBM 704 was used to simulate the interceptor portion of the run. More will be said about this later. The interceptor is vectored on a pure collision or constant true bearing course until AI radar detection occurs. The detection range capability of the AN/APQ-72 radar is described by the contour on Fig. 1. The interceptor continues to fly a pure collision or constant true bearing course until AI radar lock-on occurs (10 secs after detection). At AI lock-on, the pilot immediately attempts to zero the error dot. His maneuver capability is restricted to 3g's. If the interceptor can reduce the error to an acceptable level ($\epsilon_L \leq 10°$) between R_{max} (maximum launch range) and R_{min} (minimum launch range); if the AI radar antenna gimbal limits are not exceeded; and if the interceptor does not get into a position from which it could not recover, the run was labeled a success.

Associated with the vectoring problem are vectoring inaccuracies. These have been defined as $1\sigma = \pm 3$ naut mi in azimuth and range, and $1\sigma = \pm 1$ naut mi in altitude throughout the Navy's study. In addition, there is a probability distribution associated with AI radar detection capability which is directly related to the vectoring inaccuracy in range. Thus, by combining the probability of vectoring inaccuracy and the probability of AI radar detection, it is possible to construct a probability grid from which individual intercept runs can be examined. Such a grid is shown on Fig. 2. In Fig. 2 the center line of the distribution in azimuth due to vectoring inaccuracy represents the initial target aspect angle (τ_0) to which CIC or AEW is attempting to vector the F4H-1. It is assumed that all approach courses are pure collision up to the point of AI radar lock-on. After examining sufficient boxes in the grid, it is possible to derive the probability of successful arrival to missile launch. The results of this phase of the study are detailed in the preceding volumes.

Pertinent interceptor runs which were successful in placing the interceptor between R_{max} and R_{min} so that error was within the computed value without exceeding AI radar gimbal limits were then selected for use in the investigation of the missile problem. The aircraft attitude and motions at the launch point (roll angle, angle of attack, velocity, etc.) were used as inputs to the IBM 704 for starting the missile simulation. There are many possible approaches which could be utilized in selecting initial interceptor conditions for missile launch. For example, for each interceptor run conducted on the REAC-cockpit simulator a missile launch and guidance sample could be investigated. This becomes time-consuming and statistically confusing. A second approach would be to run many runs on the REAC and select average conditions for starting the missile phase investigation. As stated previously, in the Navy's study this second approach is essentially the procedure that was followed. The average of many runs from boxes in the probability grid were compared with runs made on the IBM 704 and close correlation was observed. From that point on, the interceptor was simulated on the IBM 704 and the results used as representative average conditions for the start of the missile phase investigation.

Missile seeker lock-on was assumed to occur at 2.14 secs after launch at R_{max}. This agrees with the 85% probability of lock-on time as given by Raytheon. For R_{min} launches seeker lock-on was assumed to occur at 1.14 secs after launch. Seeker lock-on times for launches between R_{max} and

R_{min} were obtained via linear interpolation. Initially, the missile seeker antenna is slaved to the AI radar antenna via the method described in the appendix. During the launching phase the missile is subjected to the noise effects resulting from ejection launching. The transients associated with ejection launch are given in the appendix. During the launch phase (prior to lock-on) the missile antenna is space stabilized. The missile trajectories were examined at seeker lock-on to establish if the tracking error was within the nominal half beamwidth of the seeker antenna ($\pm$ 6°).

Checkout Runs

Before the actual investigation of the missile launch and guidance phase was started, it was important to make several checkout runs to insure that all instrumentation used in the simulation program was operating correctly. These checkout runs were made at 30,000 ft altitude because:

1. The program on the computer at that time was for 30,000 ft altitude.

2. Interceptor slowdown at 30,000 ft altitude is negligible and can be ignored.

3. The results can be compared with some actual test firings made at NMC, Pt. Mugu.

The checkout runs were made for the following three specific reasons.

1. To insure that simulation instrumentation was operating correctly.

2. To determine the number of REAC runs necessary for establishing the input conditions for interceptor at missile launch (inputs to IBM 704).

3. To compare results of checkout runs with actual test firings.

Ten interceptor runs were made on the REAC-cockpit simulator for each tactical conditions. (This is the initial phase of the co-altitude attack simulation program mentioned previously). From these runs, one run was selected which represented the average and the results were used as inputs for the IBM 704. These inputs are shown as initial conditions on Table I.

TABLE I

CO-ALTITUDE ATTACKS - INITIAL CONDITIONS AT MISSILE LAUNCH
30,000 Ft ALTITUDE INVESTIGATION

$\tau_0 = 45°$ B-47 Size Target V_T = M 2.0 V_F = M 2.0

(1) Fighter Course	(2) Range Interlock Condition	Range from the Target			Steering Error	
		(3) R_X (ft)	(4) R_Y (ft)	(5) R_Z (ft)	(6) Azimuth ϵ_a (deg)	(7) Elevation ϵ_e (deg)
A-5	R_{max}	-10,700	-1,104	-570	0	1.390
B-1	R_{max}	6,600	-16,560	1800	5.25	0.08
E-1	R_{max}	28,440	-24,120	1920	2.5	5.31
	R_{min}	10,860	-13,410	-30	-1.23	4.48
F-2	R_{max}	31,200	20,220	5070	-4.79	-1.0
	R_{min}	18,000	8,730	-1200	0.56	4.92
F-3	R_{max}	29,880	22,530	-1110	-1.12	4.60
	R_{min}	14,040	-11,850	-210	-2.73	-3.48
G-6	R_{max}	30,240	-21,810	1110	-3.03	-0.81
	R_{min}	16,110	10,950	240	-0.570	-4.55

The attack geometry associated with Table I is shown on Fig. 3. For the runs of Table I, the initial target aspect angle (τ_o) to which the interceptor is being vectored is 45°. Referring to Fig. 2, τ_o would be the center line of the vectoring distribution and in this case would be 45°. A description of the first column on Table I can best be given by referring to Fig. 2. The letter and number designation associated with each fighter course designates the ray and block in the probability grid from which the intercepts start. For example, B-1 would be in the third ray from the center lines and would correspond to the first block. The second column described the range at which the missile was launched. This phase of the investigation was restricted to either R_{max} or R_{min} launches. The third, fourth, and fifth columns describe the components of range along the X, Y, Z axes. The sixth and seventh columns give the azimuth (ϵ_a) and elevation (ϵ_e) steering errors at launch as compared to the computed lead pursuit course. For this phase both interceptor and target velocities were M 2.0. As stated before, interceptor slowdown at 30,000 ft is negligible and was ignored. Throughout this study the target is assumed to be of B-47 size, flying at M 2.0. For this initial missile launch and guidance investigation, the target signal was assumed to be noise-free and transients due to ejection launch were not present (no noise conditions). One noise-free run was made on the IBM 704 for each of the ten runs made on the REAC. It is important that the reader understand clearly the meaning of "no noise" as used in this and succeeding phases of the Navy's Air to Air Missile Study. The term "no noise" as used here applies only to the missile launch and guidance phase. During the runs involved in this type of investigation, missile launching transients, target noise effects on seeker operation, and radome noise, were not simulated. However, noise effects on the interceptor portion of the investigation were present. As stated previously, the average of ten REAC runs were employed in this phase to get inputs for missile launch. On these REAC runs target noise was present. The results of this investigation are shown on Table II. An examination shows that the results obtained are as expected. When the missile is launched at R_{max} it has time to essentially zero the error. When the missile is launched at R_{min} it has more difficulty in reducing the initial launch errors. The results obtained indicated that the simulation program was correct and all simulation errors had been removed. An examination of Column 7 of Table II indicates that the miss distances obtained are as to be expected in this no noise condition. This is agreed to by Raytheon.

TABLE II

MISS DISTANCES RESULTING FROM CHECKOUT RUNS
30,000 FT CO-ALTITUDE ATTACKS
$\tau_o = 45°$ B-47 Size Target $V_T = M\ 2.0$ $V_F = M\ 2.0$ $V_T/V_F = 1.0$

(1) Fighter Course	(2) Range Interlock Condition	(3) Noise Condition	Miss Distance at Target (4) R_X (ft)	(5) R_Y (ft)	(6) R_Z (ft)	(7) Overall Miss Distance R_{MT} (ft)
A-5	R_{max}	0	0.02	0.003	0.003	0.02
B-1	R_{min}	0	0.22	0.71	0.24	0.78
E-1	R_{max}	0	-0.46	-0.34	-0.04	0.57
E-1	R_{min}	0	-0.68	-3.51	-4.21	10.27
F-2	R_{max}	0	-0.47	-0.08	-0.67	0.82
F-2	R_{min}	0	-5.28	-1.37	-22.53	23.18
F-3	R_{max}	0	-0.15	0.15	0.052	0.22
F-3	R_{min}	0	-0.31	-8.45	-3.53	12.37
G-6	R_{max}	0	-0.12	0.057	-0.15	0.20
G-6	R_{min}	0	-3.58	2.66	-1.69	4.77

Tactical Investigation

In this phase of the study, the target employed is of B-47 size, flying M 2.0 at 50,000 ft. From the preceding checkout runs it was determined that the spread in initial conditions (conditions at the time of launch) was small regardless of the number of interceptor trajectories examined. It was decided that the complete problem, including the interceptor phase, would be simulated on the IBM 704. Thus, as stated previously, the interceptor conditions employed at missile launch would be the average of many runs made with the pilot in the loop (REAC cockpit simulator runs). This process was used for all of the tactical co-altitude study described in the following section, and for the complete pull-up attack investigation which is detailed later in this report.

Table III shows the initial conditions at launch. The description of the headings given previously for Table I applies equally well here. It is observed that two aspect angles were examined; 15° was selected because it lies in the region of high probability of success when high speed targets are considered; 60° was selected because it represents approximately the outer boundary for successful attacks when high speed targets are considered. For the case of $\tau_o = 15°$, three launch conditions were examined - R_{max}, R_{min}, and $(R_{max}+R_{min})/2$. For the case of $\tau_o = 60°$ only one block (D-1) in the probability grid was examined. This was the case because D-1 represented the only block where the interceptor arrived at the launch point with $\epsilon_L \leq 10°$. For these intercepts two launch conditions were examined - R_{max} and a shorter range which corresponds to time of flight for a missile launched at R_{max} plus 2 secs (T_F + 2). This was done because the interceptor was unable to reach R_{min} on these runs. Referring to the Steering Error columns on Table III it is seen that only those interceptor courses which were successful ($\epsilon_L \leq 10°$) or marginally unsuccessful were selected for the missile miss distance study. Referring to the Fighter Velocity column, it is seen that the interceptor slowdown is included. The target is of B-47 size. The interceptor is flying at V_{max} at the beginning of the intercept run and $V_T/V_F = 1.0$.

Several conditions have been given for selecting the intercept courses to be used for investigation of the missile miss distance. These conditions can be summarized as follows:

TABLE III

INITIAL CONDITIONS AT MISSILE LAUNCH
50,000 FT CO-ALTITUDE ATTACKS
B-47 Size Target V_T = M 2.0 V_F = V_{max} V_T/V_F = 1.0

(1) Fighter Course	(2) Initial Target Aspect Angle τ_o (deg)	(3) Range Interlock Condition	Range From Target at Launch (4) R_X (ft)	(5) R_Y (ft)	(6) R_Z (ft)	Steering Error (7) Azimuth ϵ_a (deg)	(8) Elevation ϵ_e (deg)	(9) Fighter Velocity V_F (ft/sec)
B-3	15	R_{max}	23910	27760	0	2.15	5.83	1797
B-3	15	$\frac{R_{max}+R_{min}}{2}$	16140	21810	0	0.78	2.57	1751
B-3	15	R_{min}	7527	14110	0	0.47	2.06	1685
D-1	15	R_{max}	34110	15060	0	1.50	4.36	1978
D-1	15	$\frac{R_{max}+R_{min}}{2}$	28070	13000	0	0.236	0.896	1956
D-1	15	R_{min}	18080	9184	0	-0.006	0.073	1949
E-1	15	R_{max}	31410	3152	0	-3.94	11.62	1952
E-1	15	$\frac{R_{max}+R_{min}}{2}$	28710	2733	0	-3.32	9.79	1944
E-1	15	R_{min}	20950	1792	0	-1.33	3.94	1918
G-3	15	R_{max}	31340	-9022	0	-3.40	9.97	1784
G-3	15	$\frac{R_{max}+R_{min}}{2}$	27300	-8340	0	-2.71	7.90	1769
G-3	15	R_{min}	19060	-6600	0	-1.34	3.96	1736
D-1	60	R_{max}	3818	32640	0	-0.014	0.241	1921
D-1	60	T_F+2	5886	12410	0	-0.022	0.338	1879

1. The initial aspect angle lies in the zone within which the the interceptor must be vectored to arrive successfully at missile launch (see Volume III of this series, Ref. 3).

2. Runs for each of the probability grids associated with the two initial aspect angles examined were not used if the launch error was excessive (see Table III).

3. Illumination of target and missile was assured by selecting only runs for which the gimbal angles of the AI radar were $\leq \pm 57^\circ$ during the missile flight.

4. Missile seeker lock-on was assured by inspecting missile-target space relationships on the simulation records at the time of missile lock-on. Only those runs where the target was within the missile beamwidth were selected. The missile-target space relationships are shown on Table IV.

The resulting Sparrow III miss distances for the initial conditions described on Table III are summarized on Table V. The first column gives the family number and is used for identification purposes throughout this report. The second column gives the associated-figure number. It is noted that th figure numbers are listed (example - 4a, 4b, 4c). These thre figures include the three projections necessary to show the resulting miss distances. These groups of three figures are included on one sheet for cross-referencing purposes. The third column gives the box in the probability grid from which the intercept course started. The fourth column gives th nitial approach aspect. The fifth column lists the range at which the m ile was launched. In this phase of the study, target noise was injected into the simulation (see Fig. 4 of the Appendix). For each of the launch conditions, 10 noise samples were investigated. The simulation was instrumented such that each of the 10 points on the same noise distribution could be selected as starting points for the missile launch and guidance investigation. The noise samples are listed from 1 to 10 in column 6 of Table V. The seventh, eighth and ninth columns give the miss distance components (X, Y, Z). These miss distances represent the nearest points of approach of the Sparrow III missile to the geometrical center of the B-47 size target. The tenth column gives the resultant missile miss distance with respect to the geometrical center of the target. Plotting these miss distances with respect to the geometrical center of the target assumes that

TABLE IV

MISSILE ANTENNA TRACKING ERROR AT SEEKER LOCK-ON
50,000 FT CO-ALTITUDE INVESTIGATION

(1) Fighter Course	(2) Initial Target Aspect Angle τ_o (deg)	(3) Range Interlock Condition	(4) Seeker Lock-on Time (sec)	Steering Error	
				(5) Azimuth ϵ_a (deg)	(6) Elevation ϵ_e (deg)
B-3	15	R_{max}	2.14	0.17	0.38
B-3	15	$\frac{R_{max}+R_{min}}{2}$	1.64	0.25	0.22
B-3	15	R_{min}	1.14	0.09	0.17
D-1	15	R_{max}	2.14	0.27	0.086
D-1	15	$\frac{R_{max}+R_{min}}{2}$	1.64	0.28	-0.11
D-1	15	R_{min}	1.14	0.13	0.011
E-1	15	R_{max}	2.14	-0.21	0.30
E-1	15	$\frac{R_{max}+R_{min}}{2}$	1.64	0.036	0.048
E-1	15	R_{min}	1.14	0.19	-0.11
G-3	15	R_{max}	2.14	-0.26	0.43
G-3	15	$\frac{R_{max}+R_{min}}{2}$	1.64	-0.016	0.19
G-3	15	R_{min}	1.14	0.095	0.099
D-1	60	R_{max}	2.14	0.25	0.11
D-1	60	T_F+2	1.14	-0.19	0.10

the geometrical center and the radar center of the target coincide. Of course, this is not true. The radar center of the target moves with aspect angle. Unfortunately, there is insufficient data available to allow use of the radar center of the B-47 size target. When such data becomes available, it will be a relatively simple task to plot miss distances with respect to the actual target radar center.

The data presented on Table V is grouped according to families. These families are grouped for a particular aspect angle, fighter course, and missile launch range. For example, the first family is for $\tau_0 = 15°$, course B-3, and R_{max} missile launch. Examining the overall miss distance it is seen that the miss varies from 13.52 ft to 55.25 ft. The mean miss distance is 24.03 ft, which represents results of 10 runs each with a different noise condition. For this first family the standard deviation in the miss distribution is 11.68 ft.

The resulting missile miss distances for each of the families of missile launches given on Table V are shown pictorially on Figs. 4a thru 17c. On each of these figures the missile miss distances for each launch are plotted with respect to the geometrical center of a B-47 size target. There are three figures corresponding to each of the families of Table V. For example, Figs. 4a thru 4c represent miss distances for Family 1 of Table V. Figure 4a gives X-Y coordinates of the miss distances, Fig. 4b shows X-Z coordinates of the miss distances, and Fig. 4c shows Y-Z coordinates of the miss distances.

The term "no noise" applies only to the missile flight portion of the run. Target noise only is neglected. The approximation of mean F4H-1 crew performance also leads to the result that there is no statistical spread in the miss distance. In actual use of the system the random nature of live crew performance will contribute an additional statistical spread to the miss distance even if a "no noise" mode were achievable.

From the results of the missile launches detailed on Table V it is possible to predict the probability that the missile will arrive within a defined area with respect to the target. However, a detailed study of the fuzing and warhead aspects of the problem is necessary before the probability of kill of the target can be defined. Such a detailed study will not be attempted at NRL as a part of the Navy's Air to Air Missile Study. Instead a simple lethality criteria will be used. A general lethality criteria

TABLE V

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$

$V_T/V_F = 1.0$

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
1	4a 4b 4c	B-3	15	R_{max}	1	0.62	-0.19	-27.95	27.96
					2	-11.82	9.25	6.59	16.40
					3	4.75	-18.15	-17.56	25.69
					4	0.29	-12.96	5.03	13.90
					5	14.33	-14.91	0.73	20.70
					6	-11.03	8.07	-15.07	20.34
					7	-5.19	1.86	-16.22	17.13
					8	-12.59	-1.54	-4.66	13.52
					9	-44.42	29.54	14.37	55.25
					10	-14.84	11.30	-22.77	29.43
								Mean	= 24.03
								σ	= 11.68
2	5a 5b 5c	B-3	15	$\frac{R_{max}+R_{min}}{2}$	1	1.06	-5.66	10.97	12.39
					2	15.24	-13.01	-4.67	20.58
					3	-33.61	11.64	33.89	49.13
					4	-33.10	19.97	-9.98	39.93
					5	-8.62	-2.72	23.44	25.13

TABLE V (Cont)

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$

V_T/V_F = 1.0

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
					6	0.45	-3.59	12.94	13.44
					7	-3.42	0.85	-4.72	5.89
					8	-43.92	30.02	-34.09	63.18
					9	-26.13	17.78	6.76	32.32
					10	-2.26	-2.15	14.34	14.67
								Mean	= 27.67
								σ	= 17.40
3	6a 6b 6c	B-3	15	R_{min}	1	-29.49	13.48	-6.15	33.00
					2	-75.13	36.77	15.58	85.09
					3	-42.24	19.18	-15.09	48.78
					4	-22.59	8.64	-1.27	24.22
					5	-40.92	16.75	-0.79	44.22
					6	-43.83	12.92	14.23	47.86
					7	-43.19	19.73	7.78	48.12
					8	-11.71	-0.12	5.80	13.06
					9	-6.53	2.33	-20.10	21.27
					10	-56.74	21.75	9.88	61.56
								Mean	= 42.72
								σ	= 20.05

TABLE V (Cont)

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$

V_T/V_F = 1.0

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
4	7a 7b 7c	D-1	15	R_{max}	1	-0.48	-8.04	3.11	8.63
					2	-1.83	-44.09	-8.68	44.97
					3	-12.87	24.91	25.98	38.22
					4	-16.05	32.90	-12.08	38.55
					5	2.09	19.84	14.82	24.85
					6	2.34	-6.38	-17.29	18.58
					7	4.70	-13.62	-14.22	20.24
					8	-12.88	25.66	-34.26	44.70
					9	-16.22	18.38	-2.96	24.69
					10	-0.44	-7.17	22.13	23.27
								Mean	= 28.67
								σ	= 10.43
5	8a 8b 8c	D-1	15	$\frac{R_{max}+R_{min}}{2}$	1	-9.16	2.81	-3.88	10.43
					2	-8.83	15.36	5.45	18.53
					3	-11.74	22.84	13.50	29.01
					4	-0.80	-15.08	21.81	26.52

TABLE V (Cont)

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$

V_T/V_F = 1.0

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
					5	-13.18	16.60	-26.23	33.73
					6	-5.95	-0.68	13.70	14.95
					7	-10.92	10.23	-10.72	18.40
					8	-9.47	-7.76	16.04	20.18
					9	4.43	-10.26	-12.71	16.92
					10	-6.76	-2.72	-21.37	22.58
								Mean	= 21.12
								σ	= 6.63
6	9a 9b 9c	D-1	15	R_{min}	1	17.33	35.31	-22.72	45.42
					2	2.13	-5.92	-49.47	49.86
					3	-1.34	2.09	-1.14	2.73
					4	-14.71	18.12	-6.88	24.33
					5	34.20	-64.61	1.08	73.11
					6	5.88	-17.82	-7.42	20.18
					7	5.41	-12.43	-39.61	41.86
					8	-4.74	3.49	-3.74	6.97

TABLE V (Cont)

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target $V_T = M\ 2.0$ $V_F = V_{Max}$

$V_T/V_F = 1.0$

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
					9	17.13	-36.44	18.59	44.35
					10	-2.04	-27.38	-24.49	36.79
								Mean =	34.56
								σ =	20.19
7	10a 10b 10c	E-1	15	R_{max}	1	-2.29	15.47	-24.56	29.12
					2	-1.67	7.68	-51.34	51.94
					3	-0.27	-11.66	-14.97	18.98
					4	-6.01	37.39	-2.44	37.95
					5	-2.89	22.43	-4.34	23.03
					6	-5.74	15.21	-5.34	17.11
					7	-1.63	11.24	14.24	18.22
					8	-4.34	66.96	10.62	67.94
					9	-1.63	14.11	-1.69	14.31
					10	-2.00	19.84	15.32	25.15
								Mean =	30.37
								σ =	16.52

TABLE V (Cont)

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$

V_T/V_F = 1.0

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
8	11a 11b 11c	E-1	15	$\frac{R_{max}+R_{min}}{2}$	1	-11.16	24.91	3.46	27.53
					2	-11.00	24.04	-57.48	63.27
					3	0.26	-17.10	-13.03	21.50
					4	-5.78	46.36	1.58	46.75
					5	-12.98	7.76	-12.31	19.50
					6	-7.87	11.55	-15.67	21.00
					7	-1.50	-8.79	-22.38	24.09
					8	-15.79	25.07	20.90	36.26
					9	-0.12	1.95	6.32	6.61
					10	-6.15	0.23	18.00	19.02
								Mean =	28.55
								σ =	15.42
9	12a 12b 12c	E-1	15	R_{min}	1	-3.75	-2.37	24.97	25.36
					2	-9.18	43.87	-25.48	51.55
					3	-3.81	5.54	-5.73	8.83

TABLE V (Cont)

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$

$V_T/V_F = 1.0$

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
					4	1.02	-14.22	-4.48	14.94
					5	-13.30	-6.48	19.42	24.41
					6	-3.34	-8.87	18.63	20.90
					7	-6.29	9.04	-0.75	11.03
					8	-4.18	30.88	-40.06	50.76
					9	2.00	-42.73	-19.23	46.90
					10	-1.03	-13.65	15.96	21.03
								Mean =	27.57
								σ =	15.40
10	13a 13b 13c	G-3	15	$\frac{R_{max}+R_{min}}{2}$	1	-16.68	-15.46	-38.21	44.46
					2	21.13	67.01	-6.61	70.57
					3	-5.49	27.66	-18.38	33.65
					4	-5.16	3.80	-20.66	21.63
					5	17.97	54.56	-11.17	58.52
					6	-3.45	-4.21	2.29	5.90

TABLE V (Cont)

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$

$V_T/V_F = 1.0$

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
					7	1.94	8.14	8.83	12.16
					8	17.51	57.12	1.86	59.77
					9	7.07	48.59	-3.17	49.21
					10	-3.56	3.46	-8.72	10.03
								Mean =	36.59
								σ =	22.07
11	14a 14b 14c	G-3	15	$\frac{R_{max}+R_{min}}{2}$	1	1.97	6.48	-8.78	11.09
					2	7.56	42.32	-48.39	64.72
					3	-9.44	-23.79	-20.23	32.63
					4	7.42	34.37	13.81	37.78
					5	0.74	2.93	-4.29	5.25
					6	1.22	14.83	-14.31	20.64
					7	-17.01	-28.29	7.22	33.79
					8	-11.44	38.27	26.23	47.79
					9	-0.75	0.52	-3.52	3.64
					10	4.39	10.97	21.38	24.43
								Mean =	28.18
								σ =	18.3

TABLE V (Cont)

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$

$V_T/V_F = 1.0$

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
12	15a 15b 15c	G-3	15	R_{min}	1	3.88	10.10	23.64	26.00
					2	8.20	30.78	-33.25	46.05
					3	-2.39	-6.05	-3.58	7.42
					4	-10.77	-26.48	-0.30	28.59
					5	-7.74	-10.96	17.43	22.00
					6	-8.63	-19.34	-8.35	22.76
					7	-15.59	-20.23	9.34	27.19
					8	3.46	16.84	-31.66	36.02
					9	-17.26	-46.47	-19.33	53.21
					10	10.88	-2.10	14.78	18.47
								Mean =	28.73
								σ =	12.70
13	16a 16b 16c	D-1	60	R'_{max}	1	-26.03	-0.001	6.71	26.88
					2	-72.93	5.17	8.59	73.61
					3	-12.82	-2.74	8.68	15.72
					4	-46.13	-1.18	8.32	46.89

TABLE V (Cont)

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$

V_T/V_F = 1.0

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
					5	-29.08	1.67	11.91	31.47
					6	-25.36	0.92	15.84	29.92
					7	-33.67	2.57	19.98	39.24
					8	-51.56	-6.41	13.45	53.67
					9	-22.76	-1.36	6.40	23.68
					10	-38.15	-0.24	4.05	38.37
								Mean =	37.94
								σ =	15.9
14	17a 17b 17c	D-1	60	$T_F + 2$	1	-9.94	-8.21	0.18	12.89
					2	-6.84	-5.73	15.26	17.68
					3	8.00	4.50	4.78	10.35
					4	4.60	1.69	24.43	24.91
					5	32.20	17.27	11.57	38.32
					6	-22.91	-12.09	-4.43	26.28
					7	-5.91	-5.53	-9.19	12.24

TABLE V (Cont)

SPARROW III 6a MISS DISTANCES - 50,000 ft CO-ALTITUDE ATTACKS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$

V_T/V_F = 1.0

(1) Family No.	(2) Fig. No	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Range Interlock Condition	(6) Noise Sample	Miss Distance at Target (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	(10) Overall Miss Dis. R_{MT} (ft)
					8	-0.84	-0.52	11.46	11.51
					9	-17.61	-8.63	8.54	21.39
					10	-9.73	-8.93	-4.88	14.08
								Mean =	18.96
								σ =	8.41

which has been used in this and other studies is that the effective lethal radius of the Sparrow III warhead is 25 ft center of gravity to center of gravity (CG to CG) or 10 ft skin to skin (S to S) (Ref. 9). In this report it will be assumed that if a missile firing results in a miss at the target that meets the miss criteria the probability of kill is unity. If it fails to meet this requirement the probability is zero. Table VI summarizes the results of this phase of the investigation. The first four columns repeat the descriptive information given previously on Table V. The fifth and sixth columns give the mean miss distance and standard deviation for each family of 10 noise sample runs presented previously on Table V. The seventh column lists the percent of the runs which passed within 25 ft CG to CG of the target. Referring to the first line on the table, it is seen that the initial approach aspect was 15°, the fighter course originated from Box B-3 of the probability grid, and the missile was launched at R_{max}. For this set of conditions 10 noise samples, as listed on Table V, were examined. This result is a mean miss distance of 24.05 ft and a standard deviation of 11.68 ft. Seventy percent of the runs were observed to be within 25 ft CG to CG of the target. Forty percent of the runs were observed to pass within 10 ft S to S of the target. Seventy percent of the runs satisfied either of these criteria. The remaining results of Table VI correspond to families of runs presented previously on Table V.

There is one additional step required to complete the desired analyses of the F4H-1/Sparrow III 6a Weapon System. It is desirable to combine the miss distance results of the target with the probability of successful arrival to missile launch for the interceptor presented earlier in Ref. 7. The result would then be a complete definition of the probability of success up to the point of missile fuzing. To do this would require much more data than is currently available. Because of limited time and funding only a small number of actual missile flights could be made on the IBM 704. For example, to define the probability of successful arrival of the missile at the fuzing point for the case of $\tau_0 = 15°$ would require that missile runs be made for all boxes in the probability grid (see Fig. 2), which resulted in successful interceptor runs. This would require that 28 additional groups of missile runs (280 computer runs) for each launch range would have to be made. Time and funding limitations will not permit this.

TABLE VI

MISS DISTANCE RESULTS
50,000 FT CO-ALTITUDE ATTACKS
B-47 Size Target V_T = M 2.0 $V_F = V_{max}$ V_T/V_F = 1.0

(1) Family Number	(2) Fighter Course	(3) Initial Target Aspect Angle τ_o (deg)	(4) Range Interlock Condition	(5) Mean Miss (ft)	(6) Standard Deviation σ (ft)	(7) Runs Within 25 ft CG to CG (%)	(8) Runs Within 10 ft S to S	(9) Runs Satisfying Either Criteria (%)
1	B-3	15	R_{max}	24.03	11.68	70	40	70
2	B-3	15	$\frac{R_{max}+R_{min}}{2}$	27.67	17.40	60	50	70
3	B-3	15	R_{min}	42.72	20.05	30	70	80
4	D-1	15	R_{max}	28.67	10.43	60	20	70
5	D-1	15	$\frac{R_{max}+R_{min}}{2}$	21.12	6.63	70	40	80
6	D-1	15	R_{min}	34.56	20.19	40	30	40
7	E-1	15	R_{max}	30.37	16.52	60	50	70
8	E-1	15	$\frac{R_{max}+R_{min}}{2}$	28.55	15.42	60	50	80
9	E-1	15	R_{min}	27.57	15.40	60	30	80
10	G-3	15	R_{max}	36.59	22.07	40	40	50
11	G-3	15	$\frac{R_{max}+R_{min}}{2}$	28.18	18.30	50	30	50
12	G-3	15	R_{min}	28.78	12.70	40	30	50
13	D-1	60	R_{max}	37.94	15.90	20	80	80
14	D-1	60	$T_F + 2$	18.96	8.41	80	70	80

INVESTIGATION OF PULL-UP ATTACKS

In this section, the investigation of the unimproved Sparrow III 6a missile flights under pull-up conditions is detailed. The additional initial conditions beyond those described previously for the co-altitude attacks are detailed below.

Initial Conditions

During the vectoring phase the interceptor flies a pure collision course to the point of AI radar lock-on, which occurs ten seconds after AI radar detection. At the time of AI radar lock-on, the interceptor begins a pull-up maneuver to obtain a lead pursuit course. The interceptor is restricted to an L/W = 3, or $C_{I_{max}}$ course. Once the error is reduced to zero, the interceptor flies a lead pursuit course as long as possible. The Sparrow III 6a is launched when the steering error is within the allowable launch error computed in the APA-128, and the range corresponds to $R_{min} \leq R \leq R_{max}$ or 6.5 naut mi, whichever is smaller. All interceptor runs are examined to see if the gimbal angles λ_e and λ_a angles are exceeded prior to missile launch. If so, these runs are considered failures and the missile is not launched.

The pull-up and launching sequence occurs in a plane which contains the interceptor's present position and target's future position, and is established by the fighter velocity vector and the correct lead pursuit course vector. This method, employed in the simulation program, is believed to be very close to the actual way pull-up attacks will be made. For a more detailed description of this simulation technique refer to Ref. 11.

After missile launch, the interceptor continues to fly a lead pursuit, L/W = 3, or $C_{I_{max}}$ course in order to illuminate the target. During this illumination phase, the AI radar gimbals must not be exceeded from missile launch until missile impact.

In the phase of the study, two initial target aspect angles are examined ($\tau_o = 0°$ head-on, and $\tau_o = 45°$). From the probability of successful arrival to missile launch studies, reported previously in Ref. 7, it is consluded that these two angles cover the extremes of likely successful approach aspects for pull-up attacks against the high speed, high altitude

targets. Runs were made from boxes in the probability grid of Fig. 2 to get the probability of placing the missile within a lethal area around the target. As in the case of the co-altitude attacks, the target is of B-47 size. The interceptor starts the attack under V_{max} conditions. The target is flying under M 2.0 conditions at either 65,000 ft or 75,000 ft altitude. It is realized that the use of a 75,000 ft target places somewhat of an unfair burden on the Sparrow III 6a. However, the choice of this altitude is based on the following reasons:

1. At the start of the Navy's Air to Air Missile Study, the maximum intended altitude of the Sparrow III 6a was understood by many to be 78,000 ft.

2. There is little difference in terms of missile requirements for 75,000 ft and the current specification altitude of 70,000 ft.

3. Use of a 75,000 ft altitude target lends itself nicely to the next phase of the Navy's Air to Air Missile Study, that is the study of Sparrow III 6b.

The initial conditions of the interceptor at the start of the pull-up maneuver are shown on Table VII for the various cases examined. The first column gives the box in the probability grid from which the intercept run originated. The second column lists the initial target aspect angle. The third column gives the target altitude. The fourth column gives the interceptor altitude at the start of pull-up. The fifth column gives the interceptor velocity at the start of pull-up. The final three columns give the X, Y, Z components of the range between the interceptor and target at the start of pull-up.

<u>Pull-up Attacks Against Nonmaneuvering Targets</u>

In the pull-up attacks against nonmaneuvering targets the investigation was restricted to initial target aspect angles of 0° and 45°. As shown on Table VII for the case of $\tau_0 = 0°$, pull-up attacks were made from interceptor altitudes of 58,000 and 50,000 ft. For the case of $\tau_0 = 45°$ pull-up attacks were made from interceptor altitudes of 58,000 ft, 50,000 ft and 40,000 ft. For each case, the interceptor starts pull-up under V_{max} conditions against a M 2.0 target.

TABLE VII

INITIAL CONDITIONS OF INTERCEPTOR AT AI RADAR
LOCK-ON RANGE (START OF PULL-UP)
PULL-UP ATTACKS - NONMANEUVERING TARGET
B-47 Size Target V_T = M 2.0 $V_F = V_{max}$ at Pull-up

(1) Fighter Course	(2) Initial Target Aspect Angle τ_o (deg)	(3) Target Altitude H_T (ftx10^3)	(4) Fighter Altitude at Pull-up H_F (ftx10^3)	(5) Fighter Velocity V_F (ft/sec)	Components of Range-Intercept to Target (6) R_X (nm)	(7) R_Y (nm)	(8) R_Z (nm)
D-1	0	65	58	1753	10.25	1.02	-1.15
C-4	0	65	58	1753	13.68	2.99	-1.15
D-2	0	65	50	2005	12.31	0.99	-2.47
C-5	0	65	50	2005	15.95	3.02	-2.47
D-4	0	75	58	1753	16.22	1.02	-2.80
C-6	0	75	58	1753	17.65	2.99	-2.80
D-4	0	75	50	2005	16.30	0.99	-4.11
C-6	0	75	50	2005	17.97	3.01	-4.11
D-1	45	65	58	1753	8.22	9.62	-1.15
E-4	45	65	58	1753	13.90	12.51	-1.15
D-1	45	65	50	2005	7.81	9.24	-2.47
E-1	45	65	50	2005	9.28	7.92	-2.47
D-1	45	65	40	2034	7.81	9.24	-4.11
E-1	45	65	40	2034	9.28	7.92	-4.11
D-1	45	75	58	1753	8.22	9.62	-2.80
E-4	45	75	58	1753	13.90	12.51	-2.80
D-1	45	75	50	2005	7.81	9.24	-4.11
E-1	45	75	50	2005	9.29	7.91	-4.11
D-2	45	75	40	2034	9.25	10.64	-5.76
E-2	45	75	40	2034	10.70	9.33	-5.76

Table VIII gives the initial conditions at missile launch. The first four columns repeat information given on Table VII. Column five gives interceptor altitude at launch. The sixth column gives the range interlock condition at launch. Launches were attempted from R_{max}, R_{min}, and $(R_{max}+R_{min})/2$. If on a particular course the interceptor could not close range to R_{min} an arbitrary launch point is selected corresponding to missile time of flight (T_F) plus 2 seconds following R_{max}.

As in the case of co-altitude attacks, seeker lock-on is assumed to occur 2.14 seconds after launch at R_{max} and 1.14 seconds after launch at R_{min}. Linear interpolation is used to determine seeker lock-on time for launches between R_{max} and R_{min}. The next three columns on Table VIII give the components of range at missile launch. The tenth and eleventh columns give the azimuth and elevation steering errors at launch. The twelfth column gives the interceptor velocity at missile launch and shows the interceptor slowdown during the pull-up maneuver.

The results of the pull-up attack missile launches are given on Table IX. The first column gives the family number and is used for identification of runs. The second column gives the figure numbers associated with each family of the missile flights examined. The next four columns give the initial conditions at the start of intercept. The seventh column gives range at missile launch. These ranges are labeled as R_{max}, $(R_{max}+R_{min})/2$, R_{min} or $T_F + 2$, and are equivalent to the previously defined ranges. The next column shows which of the 10 noise samples were examined. The final four columns give missile miss distance results. The first three of these gives the components of miss in the X, Y, and Z direction. The twelfth column shows the resulting overall miss distance for each of the noise samples examined. Finally, at the end of each family, provided sufficient noise samples were examined, the mean miss distance ($1\ \sigma$ value of miss distance) and no noise miss distance are tabulated. For example on Family 1 the mean miss distance = 46.4 ft, $1\ \sigma$ value of miss distance = 15.3 ft, and no noise miss distance = 11.2 ft. Referring to the first column again, it is seen that for each family three figures are given (for some families no data is given). For example, for the first family Figs. 18a, 18b, and 18c show the results; Fig. 18a the resulting miss distances in the X-Y plane; Fig. 18b the X-Z plane; Fig. 18c the Y-Z plane. As in the case of the co-altitude attacks the resulting miss distance for the case where no noise was used is shown by the black circle. The mean miss distance for the

TABLE VIII

INITIAL CONDITIONS AT MISSILE LAUNCH FOR PULL-UP ATTACKS AGAINST NONMANEUVERING TARGETS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$ at Pull-up

(1) Fighter Course	(2) Initial Target Aspect Angle τ_o (deg)	(3) Target Altitude H_T (ftx10^3)	(4) Fighter Altitude at Pull-up (ftx10^3)	(5) Fighter Altitude at Launch Point (ftx10^3)	(6) Range Interlock Condition	Range from Target at Launch (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	Steering Error at Launch (10) AZ ϵ_a (deg)	(11) EL ϵ_e (deg)	(12) Fighter Velocity V_F (ft/sec)
D-1	45	75	50	57.671	R_{max}	17550	28040	-17330	-0.489	0.828	1604
D-1	45	75	50	66.828	$T_F + 2$	-1075	13220	-8171	6.597	6.636	1195
E-1	45	75	50	57.844	R_{max}	23020	20060	-17160	-5.958	7.66	1601
E-1	45	75	50	60.635	$\frac{R_{max}+R_{min}}{2}$	16840	16180	-14360	-0.472	4.549	1487
E-1	45	75	50	64.288	R_{min}	9277	11870	-10710	3.142	6.118	1340
D-2	45	75	40	54.267	R_{max}	15600	26670	-20730	-0.033	0.446	1654
D-2	45	75	40	65.005	$T_F + 2$	-1653	12860	-9995	2.548	4.433	1229
E-2	45	75	40	52.555	R_{max}	23570	21480	-22450	-2.36	4.356	1667
E-2	45	75	40	57.962	$\frac{R_{max}+R_{min}}{2}$	14540	16210	-17040	-0.136	1.384	1492
E-2	45	75	40	62.815	R_{min}	6659	11590	-12180	1.538	4.453	1294

TABLE VIII

INITIAL CONDITIONS AT MISSILE LAUNCH FOR PULL-UP ATTACKS AGAINST NONMANEUVERING TARGETS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$ at Pull-up

(1) Fighter Course	(2) Initial Target Aspect Angle τ_o (deg)	(3) Target Altitude H_T ($ft x 10^3$)	(4) Fighter Altitude at Pull-up ($ft x 10^3$)	(5) Fighter Altitude at Launch Point ($ft x 10^3$)	(6) Range Interlock Condition	Range from Target at Launch (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	Steering Error at Launch (10) AZ ϵ_a (deg)	(11) EL ϵ_e (deg)	(12) Fighter Velocity V_F (ft/sec)
D-1	45	65	50	60.176	R_{min}	4381	15240	-4824	1.286	3.471	1564
E-1	45	65	50	54.630	R_{max}	26760	24500	-10370	-0.024	0.227	1738
E-1	45	65	50	56.507	$\frac{R_{max}+R_{min}}{2}$	19930	20060	-8493	-0.059	0.496	1687
E-1	45	65	50	59.096	R_{min}	11180	13950	-5904	0.207	1.782	1572
D-1	45	65	40	47.464	R_{max}	18540	27970	-17540	-1.052	2.218	1828
D-1	45	65	40	52.255	$\frac{R_{max}+R_{min}}{2}$	10200	20290	-12740	-0.046	0.648	1721
D-1	45	65	40	57.157	R_{min}	2367	12490	-7842	0.430	2.962	1520
E-1	45	65	40	49.236	R_{max}	20140	16980	-15760	-6.058	8.747	1776
E-1	45	65	40	51.456	$\frac{R_{max}+R_{min}}{2}$	15760	14090	-13540	-3.510	4.136	1705
E-1	45	65	40	55.023	R_{min}	9459	10260	-9977	-0.013	1.691	1570
D-1	45	75	58	64.037	R_{max}	17850	31380	-10960	-0.346	1.580	1343
E-4	45	75	58	66.970	R_{max}	19650	3900	-8030	0.683	1.817	1154

TABLE VIII

INITIAL CONDITIONS AT MISSILE LAUNCH FOR PULL-UP ATTACKS AGAINST NONMANEUVERING TARGETS

B-47 Size Target V_T = M 2.0 $V_F = V_{Max}$ at Pull-up

(1) Fighter Course	(2) Initial Target Aspect Angle τ_o (deg)	(3) Target Altitude H_T (ftx10^3)	(4) Fighter Altitude at Pull-up (ftx10^3)	(5) Fighter Altitude at Launch Point (ftx10^3)	(6) Range Interlock Condition	Range from Target at Launch (7) R_X (ft)	(8) R_Y (ft)	(9) R_Z (ft)	Steering Error at Launch (10) AZ ϵ_a (deg)	(11) EL ϵ_e (deg)	(12) Fighter Velocity V_F (ft/sec)
D-1	0	65	58	59.008	R_{max}	36720	5308	-5992	2.49	8.89	1606
C-4	0	65	58	60.103	R_{max}	34200	12720	-4897	2.99	6.58	1456
D-2	0	65	50	55.156	R_{max}	25670	3950	-9844	1.53	11.88	1713
C-5	0	65	50	56.301	R_{max}	34540	10650	-8699	-0.011	0.074	1658
D-4	0	75	58	64.488	R_{max}	36750	3835	-10510	0.281	1.74	1304
C-6	0	75	58	65.387	R_{max}	33820	10280	-9613	0.861	2.05	1216
D-4	0	75	50	59.564	R_{max}	33430	3717	-15440	0.691	6.894	1528
C-6	0	75	50	60.914	R_{max}	34630	10310	-14090	-0.022	0.702	1444
D-1	45	65	58	60.695	R_{max}	19410	32500	-4305	-0.144	0.777	1535
D-1	45	65	58	61.909	$\frac{R_{max}+R_{min}}{2}$	9355	23340	-3091	-0.123	2.104	1414
E-4	45	65	58	61.695	R_{max}	22610	31750	-3305	-0.192	0.880	1409
E-4	45	65	58	62.574	$\frac{R_{max}+R_{min}}{2}$	11780	23300	-2426	0.408	2.299	1293
D-1	45	65	50	55.411	R_{max}	19330	3290	-9589	-0.037	0.349	1782
D-1	45	65	50	57.658	$\frac{R_{max}+R_{min}}{2}$	11990	23190	-7342	-0.115	0.946	1708

missile flights where noise was used is indicated by the black square. The same definition given previously for no noise as used in co-altitude attacks applies equally well here.

For each case where figures are given, three figures are used to illustrate the resulting miss distances. Each of these three figures carry the same numerical designation and are separated by a, b, c. However, referring to the table, it is seen that for some cases no figures are included. For example, no figures were plotted for Family 5. For this particular family only five noise samples were examined. Referring to the results it is seen that no more samples were warranted because of the large miss distances encountered. No attempt was made to present the results graphically because many of the points would be off the scale used for the other figures. For these same reasons figures are not given for Families 6, 7, and 8. The results of the pull-up investigation are illustrated by Figs. 18a thru 32c.

For the case of Family 10 only one noise sample was run. The miss distance was such that no additional runs were warranted. In addition, examination of launches from R_{min} for this particular situation was not warranted. For the case of Family 12 only one noise sample was examined. The reason for this is that the miss distance was large and upon examination of the run it was found that at missile seeker lock-on the missile would not be able to see the target because the target was outside the seeker antenna beam. Thus, no additional noise samples were warranted and no figures are given. Obviously, failing at longer range, it would be a waste of time to examine launches made from R_{min}.

Family 15 gives the results for launches from R_{min} for an intercept which started from $\tau_o = 45°$, Box D-1, $H_F = 50{,}000$ ft, and $H_T = 65{,}000$ ft. Again only one noise sample is examined. The reasons why no additional runs are examined are the same as those given above for Family 12. For the case of Family 18, only five noise samples were investigated. While the miss distances are smaller than preceding R_{min} launches, the results are still much too large (overall miss varies from 110.4 to 157.8 ft). No figures are given to show these results.

Table IX shows that only one noise sample was examined for Family 21. Again the reasons for this cursory examination are excessive miss distance and seeker unable to see the target at lock-on. For the case of Family 24

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
1	18a 18b 18c	D-1	0	65	58	R_{max}	1	-12.0	26.4	-10.4	30.8
							2	13.2	-28.1	51.6	60.2
							3	-31.3	54.0	1.9	62.4
							4	-13.0	13.0	42.7	46.5
							5	-22.9	40.5	-29.2	54.9
							6	-1.9	26.2	4.5	26.7
							7	-13.1	-11.1	-65.4	67.6
							8	5.8	-54.3	-1.8	54.7
							9	-5.9	20.2	-6.1	21.9
							10	6.4	9.3	36.6	38.3
										Mean	= 46.4
										σ	= 15.3
										No Noise	= 11.2

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up $V_T = M\ 2.0$

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
2	19a 19b 19c	C-[illegible]	0	65	58	R_{max}	1	-35.8	59.1	-0.1	69.1
							2	-0.1	-12.5	10.5	16.3
							3	-63.8	123.4	21.4	140.5
							4	-15.3	67.7	58.3	90.7
							5	-73.9	80.4	-17.1	110.5
							6	-15.7	34.0	19.8	42.3
							7	-40.6	51.5	-76.4	100.7
							8	-17.8	18.6	-1.4	25.8
							9	-21.6	52.1	-4.7	56.6
							10	-0.2	13.9	21.7	25.8
										Mean =	67.8
										σ =	39.6
										No Noise=	22.8

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
3	20a 20b 20c	D-2	0	65	50	R_{max}	1	-7.9	14.4	4.6	17.1
							2	-71.1	-45.1	-163.2	183.7
							3	24.6	-35.0	39.7	58.4
							4	-44.5	0.3	-52.7	69.0
							5	15.4	-50.1	16.1	54.8
							6	9.5	-1.3	36.2	37.4
							7	19.4	-61.6	17.0	66.8
							8	0.7	-20.1	27.5	34.1
							9	6.0	-47.3	6.1	48.0
							10	-21.4	7.7	-34.0	40.9
										Mean	= 61.0
										σ	= 43.6
										No Noise	= 53.7

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up $V_T = M\ 2.0$

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T ($ftx10^3$)	(6) Fighter Altitude at Pull-up H_F ($ftx10^3$)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
4	21a 21b 21c	C-5	0	65	50	R_{max}	1	-21.8	36.9	-12.1	44.5
							2	5.4	21.7	45.1	50.3
							3	-87.3	127.8	-50.6	162.8
							4	-49.1	63.0	17.1	81.7
							5	-53.4	71.5	-50.1	102.3
							6	-23.0	36.6	-18.6	47.1
							7	-76.2	47.7	-80.4	120.7
							8	-25.7	-24.6	-10.6	37.1
							9	-17.1	38.3	-15.6	44.7
							10	4.9	4.3	17.5	18.7
										Mean	= 71.0
										σ	= 42.7
										No Noise=	4.7

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
5		D-4	0	75	58	R_{max}	1	-81.2	-0.6	-91.2	122.0
							2	-35.6	-32.1	-121.8	130.9
							3	-115.2	38.2	-117.1	168.6
							4	-27.6	-30.0	-28.0	49.5
							5	-45.7	50.5	-144.1	159.4
										Mean	= 126.1
										σ	= 41.9
										No Noise	= 120.8
6		C-6	0	75	58	R_{max}	1	-83.6	45.3	-147.2	175.2
							2	-78.1	2.3	-152.1	171.0
							3	-49.1	16.1	-152.4	160.9
							4	-71.2	61.3	-119.3	151.9
							5	-53.7	40.2	-118.8	136.5
										Mean	= 159.1
										σ	= 13.9

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
7		D-4	0	75	50	R_{max}	1	-31.9	76.8	-43.2	93.7
							2	-80.5	-35.8	-157.7	180.7
							3	-57.1	130.2	-92.9	169.8
							4	-18.8	52.4	-27.1	61.9
							5	-63.3	71.0	-118.8	152.2
										Mean	= 131.7
										σ	= 45.9
										No Noise=	25.7
8		C-6	0	75	50	R_{max}	1	-64.2	73.5	-105.6	143.8
							2	-50.9	17.6	-105.6	118.5
							3	-63.6	106.1	-86.3	150.7
							4	-52.6	136.7	-39.5	151.7
							5	-52.2	78.6	-79.5	123.4
										Mean	=137.6
										σ	= 14.2
										No Noise=	119.2

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
9	22a 22b 22c	D-1	45	65	58	R_{max}	1	-1.6	2.1	7.0	7.4
							2	-45.3	32.5	31.7	64.2
							3	-3.9	4.0	16.6	17.6
							4	-9.2	9.2	30.5	33.2
							5	-3.7	-3.3	-34.5	34.9
							6	-28.9	14.5	17.1	36.6
							7	-10.4	-1.0	-57.0	57.9
							8	-40.6	-13.7	-67.8	80.2
							9	-12.5	4.2	-21.8	25.5
							10	-23.0	9.0	17.5	30.3
										Mean =	38.8
										σ =	21.1
										No Noise =	10.5
10		D-1	45	65	58	$\frac{R_{max}+R_{min}}{2}$	1	-182.6	43.7	62.4	197.9

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T ($ft \times 10^3$)	(6) Fighter Altitude at Pull-up H_F ($ft \times 10^3$)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
11	23a 23b 23c	E-4	45	65	58	R_{max}	1	-5.2	3.9	5.8	8.7
							2	-61.6	14.5	37.2	73.4
							3	-9.5	0.8	20.1	22.2
							4	-17.6	9.9	34.1	39.6
							5	-11.8	-10.3	-36.2	39.5
							6	-25.0	12.8	14.8	31.7
							7	-15.9	-4.5	-61.6	63.8
							8	-44.8	-11.2	-75.9	88.9
							9	-12.1	4.2	-18.2	22.2
							10	-24.1	12.5	12.3	29.9
										Mean =	42.0
										σ =	24.1
										No Noise =	11.7
12		E-4	45	65	58	$\frac{R_{max}+R_{min}}{2}$	1	-139.8	-21.6	10.6	141.9

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
13	24a 24b 24c	D-1	45	65	50	R_{max}	1	-9.9	1.2	-15.8	18.7
							2	-61.5	-3.4	-11.4	62.6
							3	-0.9	-7.6	24.8	25.9
							4	-29.7	26.0	20.1	44.3
							5	13.3	-6.9	7.0	16.5
							6	-18.4	-4.7	-29.9	35.4
							7	-4.5	8.1	15.5	18.0
							8	-26.7	26.9	36.7	52.8
							9	-25.5	11.6	3.9	28.3
							10	-27.5	-11.8	-66.8	73.2
										Mean =	37.6
										σ =	18.9
										No Noise =	6.4

TABLE IX

STARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
14	25a 25b 25c	D-1	45	65	50	$\frac{R_{max}+R_{min}}{2}$	1	-38.4	17.8	-0.7	42.3
							2	-31.2	13.2	-6.8	34.6
							3	-91.9	1.6	8.5	92.3
							4	-67.0	-25.2	3.6	71.7
							5	-69.4	9.6	12.1	71.1
							6	-30.5	16.9	7.4	35.6
							7	-56.2	25.7	12.1	62.9
							8	-70.3	19.7	4.5	73.1
							9	-28.3	13.9	3.0	31.6
							10	-30.5	19.5	15.2	39.3
										Mean =	55.4
										σ =	20.3
										No Noise=	43.3
15		D-1	45	65	50	R_{min}	1	-92.4	5.2	20.3	94.7

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T ($ft \times 10^3$)	(6) Fighter Altitude at Pull-up H_F ($ft \times 10^3$)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
16	26a 26b 26c	E-1	45	65	50	R_{max}	1	-3.4	11.0	15.4	19.3
							2	2.7	-23.6	-37.9	44.8
							3	-3.8	0.5	-12.3	12.8
							4	-33.5	-15.1	-54.2	65.5
							5	-4.7	2.0	4.8	7.0
							6	-6.4	2.5	3.8	7.9
							7	-20.1	13.1	56.3	61.2
							8	-36.8	32.8	8.4	50.0
							9	-13.0	12.2	-1.9	17.9
							10	-18.4	19.5	6.7	27.6
										Mean	= 31.4
										σ	= 21.0
										No Noise	= 9.6

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T ($ft \times 10^3$)	(6) Fighter Altitude at Pull-up H_F ($ft \times 10^3$)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
17	27a 27b 27c	E-1	45	65	50	$\frac{R_{max}+R_{min}}{2}$	1	-35.4	-1.2	20.9	47.1
							2	-42.0	42.8	22.8	64.2
							3	-49.9	60.3	23.1	81.6
							4	-41.7	32.1	48.5	71.5
							5	-34.5	35.5	5.6	49.8
							6	-21.7	31.7	47.6	61.2
							7	-49.1	49.7	7.8	70.2
							8	-11.9	13.1	3.1	18.0
							9	-33.8	39.5	28.6	59.3
							10	-22.9	18.6	49.3	57.4
										Mean =	57.4
										σ =	17.1
										No Noise =	33.3

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T ($ft x 10^3$)	(6) Fighter Altitude at Pull-up H_F ($ft x 10^3$)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
18		E-1	45	65	50	R_{min}	1	-37.5	-81.9	-113.4	144.8
							2	22.2	-109.3	-111.6	157.8
							3	4.8	-59.7	-116.5	131.0
							4	-37.5	-49.1	-114.2	129.8
							5	-9.9	-55.2	-95.1	110.4
										Mean	= 134.8
										σ	= 15.6
										No Noise	= 130.6

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
19	28a, 28b, 28c	D-1	45	65	40	R_{max}	1	-16.5	13.6	6.9	22.5
							2	-76.3	61.6	23.1	100.8
							3	-12.9	18.9	17.9	29.1
							4	-22.3	15.6	3.4	27.5
							5	-1.2	-4.3	-8.5	9.6
							6	-43.9	24.5	-3.4	50.4
							7	-18.2	-0.7	-22.0	28.5
							8	-41.1	-6.6	-53.0	67.4
							9	-40.6	9.2	-24.9	48.5
							10	-26.5	6.1	-13.4	30.3
										Mean =	41.5
										σ =	25.1
										No Noise =	18.9

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
20	29a 29b 29c	D-1	45	65	40	$\frac{R_{max}+R_{min}}{2}$	1	-33.4	6.4	-13.0	36.4
							2	-31.9	-2.9	-27.3	42.1
							3	-65.9	16.9	-22.0	71.5
							4	-46.6	8.9	-20.8	51.8
							5	-51.6	10.4	-20.9	56.7
							6	-28.6	11.2	-2.6	30.8
							7	-44.3	6.5	-21.5	49.7
							8	-64.2	26.4	-8.4	69.9
							9	-26.3	6.3	-9.5	28.7
							10	-31.4	14.0	-1.9	34.4
										Mean =	47.2
										σ =	14.6
										No Noise =	39.3
21		D-1	45	65	40	R_{min}	1	-221.3	75.8	38.2	237.0

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
22	30a 30b 30c	E-1	45	65	40	R_{max}	1	-38.6	-2.3	-46.0	60.1
							2	-71.3	56.0	-25.0	94.1
							3	-78.7	44.7	-46.0	101.5
							4	-77.4	56.5	-33.0	101.3
							5	-58.3	19.5	-46.6	72.2
							6	-40.8	24.4	-22.5	52.6
							7	-52.4	-0.4	-65.1	83.6
							8	-40.5	18.9	-27.4	52.4
							9	-42.2	54.8	5.9	69.4
							10	-33.7	20.8	-16.3	42.9
										Mean	= 73.5
										σ	= 20.3
										No Noise	= 38.1

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T ($ft \times 10^3$)	(6) Fighter Altitude at Pull-up H_F ($ft \times 10^3$)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
23	31a 31b 31c	E-1	45	65	40	$\frac{R_{max}+R_{min}}{2}$	1	-53.1	25.5	-30.8	66.5
							2	-96.2	34.9	-70.7	124.4
							3	-71.3	39.8	-41.0	91.4
							4	-52.7	69.1	13.6	87.9
							5	-40.8	31.8	-12.2	53.2
							6	-64.5	55.6	-12.9	86.1
							7	-72.9	11.6	-69.1	101.1
							8	-26.2	37.5	10.7	47.0
							9	-41.0	14.9	-28.4	52.1
							10	-35.3	33.5	-4.0	48.9
										Mean	= 75.9
										σ	= 24.8
										No Noise	= 56.3

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
24		E-1	45	65	40	R_{min}	1	12.5	-80.1	-67.5	105.5
							2	21.4	-101.5	-80.4	131.2
							3	-0.03	-76.1	-75.9	107.4
							4	-29.6	-40.0	-68.0	84.2
							5	7.5	-77.2	-66.6	102.3
										Mean	= 106.1
										σ	= 15.1
										No Noise	= 88.2
25		D-1	45	75	58	R_{max}	1	-142.6	65.5	-67.6	170.9
26		E-4	45	75	8	R_{max}	1	-1258.5	906.0	-82.3	1552.9

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
27		D-1	45	75	50	R_{max}	1	-63.6	18.6	-34.3	74.7
							2	-98.6	35.8	-45.0	114.2
							3	-50.6	15.4	-26.8	59.3
							4	-83.4	22.1	-54.1	101.9
							5	-160.7	46.6	-103.9	196.9
							6	-72.0	17.8	-46.9	87.8
							7	-83.8	27.7	-46.5	99.8
							8	-86.3	18.0	-61.8	107.7
							9	-95.0	20.8	-65.9	117.5
							10	-136.3	47.7	-71.5	161.2
										Mean	=112.1
											= 38.3
										No Noise	= 56.7
28		D-1	45	75	50	$T_F + 2$	1	-2130.9	1126.1	-55.1	2410.8

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T ($ft \times 10^3$)	(6) Fighter Altitude at Pull-up H_F ($ft \times 10^3$)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
29		E-1	45	75	50	R_{max}	1	-70.3	-18.1	-84.7	111.5
							2	-88.8	25.4	-90.0	128.9
							3	-93.3	11.1	-115.4	148.9
							4	-108.1	23.4	-120.0	163.2
							5	-91.5	15.8	-103.7	139.2
										Mean	= 138.3
										σ	= 17.9
										No Noise	= 93.3
30		E-1	45	75	50	$\frac{R_{max}+R_{min}}{2}$	1	-197.2	31.0	-172.2	263.6
							2	-274.9	61.4	-224.8	360.4
							3	-229.7	65.0	-170.9	293.6
							4	-174.8	42.0	-134.5	224.6
							5	-184.5	48.0	-139.2	236.1
										Mean	= 275.7
										σ	= 48.4

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	Miss Distance at Target (10) R_Y (ft)	Miss Distance at Target (11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
31		E-1	45	75	50	R_{min}	1	-490.8	275.7	-90.2	570.1
							2	-617.3	336.0	-116.9	712.4
							3	-277.9	136.8	-56.9	314.9
							4	-658.8	351.9	-140.8	760.0
							5	-290.7	141.6	-60.8	329.0
										Mean =	537.3
										σ =	186.6

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
32	32a 32b 32c	D-2	45	75	40	R_{max}	1	-30.0	0.8	-21.3	36.8
							2	-84.1	36.3	-18.0	93.3
							3	-45.0	19.4	-10.4	50.1
							4	-42.8	0.7	-29.5	52.0
							5	-30.3	-9.3	-33.6	46.2
							6	-45.2	-1.5	-35.4	57.5
							7	-33.9	0.9	-23.1	41.1
							8	-45.0	-8.9	-42.9	62.8
							9	-48.3	-4.9	-40.4	63.1
							10	-34.0	1.0	-23.2	41.2
										Mean =	54.4
										σ =	15.6
										No Noise =	44.6

TABLE IX

SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
NONMANEUVERING TARGET

B-47 Size Target $V_F = V_{max}$ at Pull-up V_T = M 2.0

(1) Family No.	(2) Fig. No.	(3) Fighter Course	(4) Initial Target Aspect Angle τ_o (deg)	(5) Target Altitude H_T (ftx10^3)	(6) Fighter Altitude at Pull-up H_F (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Dis. R_{MT} (ft)
33		E-2	45	75	40	R_{max}	1	-96.4	34.2	-59.7	118.5
							2	-91.5	38.4	-52.5	112.3
							3	-97.8	33.2	-64.0	121.6
							4	-98.1	3.0	-95.7	137.1
							5	-126.7	25.9	-99.4	163.2
										Mean	= 130.5
										σ	= 18.5
										No Noise	= 112.1
34		E-2	45	75	40	$\frac{R_{max}+R_{min}}{2}$	1	-123.7	22.8	-86.6	152.7
							2	-112.0	4.9	-91.5	144.7
							3	-143.3	33.5	-98.6	177.2
							4	-128.2	44.5	-71.7	153.2
							5	-131.1	50.5	-70.0	156.9
										Mean	= 156.9
										σ	= 11.4
										No Noise	= 146.7
35		E-2	45	75	40	R_{min}	1	-433.6	237.0	-11.5	494.2

only five noise samples were examined because of the excessive miss distances resulting. Figures are not given for Families 25 and 26 for the same reason. Ten noise sample runs were made for Family 27. However, the misses were such that they would fall off the scale of the figures. Thus, no figures are included. For this particular situation, the interceptor was unable to close range on the target to R_{min}. Thus, no families are given for $(R_{max}+R_{min})/2$ and R_{min} launches. Instead a launch point corresponding to $T_F + 2$ is investigated. These results are given in Family 28. Again, the miss is so large that it was obvious that a detailed investigation was unnecessary. Thus only one noise sample was used.

The reasons for not giving figures describing the results of some of the remaining families have been detailed above. The time histories of missile parameters will be given in a succeeding volume of this series. A study of these parameter variations will explain further the reasons for the failures that occurred.

From the results shown on Table IX it is possible to predict the probability that the missile will arrive within a defined area with respect to the target. As in the case of the co-altitude attack situation a detailed study of the fuzing and warhead aspects of the problem will not be investigated. The same simple criteria will be applied to the pull-up attacks as was applied to the co-altitude case. The first of these assumes that if the missile passes within 25 ft CG to CG of the target the probability of kill is unity. The second criterion is that if the missile passes within 10 ft S to S of the target the probability of kill will be unity. Primary emphasis will be placed on the first criterion. Table X summarizes the results for all pull-up attack cases examined and presented on Table IX, where five or more noise samples were investigated. The first six columns of Table X repeat information given previously on Table IX. Column seven shows the mean miss distance for each of the families examined; column eight the calculated standard deviation of the miss (σ) in ft; column nine gives the actual percentage (varying from 0 to 50) of missile runs which were observed to pass within 25 ft CG to CG of the target. Column ten shows the results when the miss distance criteria of 10 ft S to S is used. It is seen that this does not yield significantly better results. If an either/or criteria is used the results of column eleven are obtained.

TABLE X

MISS DISTANCE RESULTS-PULL-UP ATTACKS-NONMANEUVERING TARGET

B-47 Size Target V_T = M 2.0 $V_F = V_{max}$ at Pull-up

(1) Family Number	(2) Fighter Course	(3) Initial Target Aspect Angle τ_o (deg)	(4) Target Altitude H_T (ftx10^3)	(5) Fighter Altitude at Pull-up H_F (ftx10^3)	(6) Range Interlock Condition	(7) Mean Miss (ft)	(8) Standard Deviation σ (ft)	(9) Runs Within 25 ft CG to CG %	(10) Runs Within 10 ft S to S %	(11) Runs Satisfying Either Criteria %
1	D-1	0	65	58	R_{max}	46.4	15.3	10	40	40
2	C-4	0	65	58	R_{max}	67.8	39.6	20	30	40
3	D-2	0	65	50	R_{max}	61.0	43.6	10	20	20
4	C-5	0	65	50	R_{max}	71.0	42.7	10	0	10
5	D-4	0	75	58	R_{max}	126.1	41.9	0	0	0
6	C-6	0	75	58	R_{max}	159.1	13.9	0	0	0
7	D-4	0	75	50	R_{max}	131.7	45.9	0	0	0
8	C-6	0	75	50	R_{max}	137.6	14.2	0	0	0
9	D-1	45	65	58	R_{max}	38.8	21.1	20	10	20
11	E-4	45	65	58	R_{max}	42.0	24.1	30	20	30
13	D-1	45	65	50	R_{max}	37.6	18.9	40	40	50
14	D-1	45	65	50	$\frac{R_{max}+R_{min}}{2}$	55.4	20.3	0	50	50
16	E-1	45	65	50	R_{max}	31.4	21.0	50	40	50
17	E-1	45	65	50	$\frac{R_{max}+R_{min}}{2}$	57.4	17.1	10	10	10
18	E-1	45	65	50	R_{min}	134.8	15.6	0	0	0
19	D-1	45	65	40	R_{max}	41.5	25.1	20	40	40
20	D-1	45	65	40	$\frac{R_{max}+R_{min}}{2}$	47.2	14.6	0	40	40
22	E-1	45	65	40	R_{max}	73.5	20.3	0	0	0
23	E-1	45	65	40	$\frac{R_{max}+R_{min}}{2}$	75.9	24.6	0	0	0

TABLE X (Cont)

MISS DISTANCE RESULTS-PULL-UP ATTACKS-NONMANEUVERING TARGET

B-47 Size Target V_T = M 2.0 $V_F = V_{max}$ at Pull-up

(1) Family Number	(2) Fighter Course	(3) Initial Target Aspect Angle τ_o (deg)	(4) Target Altitude H_T (ftx10^3)	(5) Fighter Altitude at Pull-up H_F (ftx10^3)	(6) Range Interlock Condition	(7) Mean Miss (ft)	(8) Standard Deviation σ (ft)	(9) Runs Within 25 ft CG to CG %	(10) Runs Within 10 ft S to S %	(11) Runs Satisfying Either Criteria %
24	E-1	45	65	40	R_{min}	106.1	15.1	0	0	0
27	D-1	45	75	50	R_{max}	112.1	38.3	0	0	0
29	E-1	45	75	50	R_{max}	138.3	17.9	0	0	0
30	E-1	45	75	50	$\frac{R_{max}+R_{min}}{2}$	275.7	48.4	0	0	0
31	E-1	45	75	50	R_{min}	537.3	186.6	0	0	0
32	D-2	45	75	40	R_{max}	54.4	15.6	0	10	10
33	E-2	45	75	40	R_{max}	130.5	18.5	0	0	0
34	E-2	45	75	40	$\frac{R_{max}+R_{min}}{2}$	156.9	11.4	0	0	0

Effect of Target Maneuver

The effects of target maneuvers on probability of successful arrival to missile launch were detailed previously in Volume IX of this series (Ref. 7). In this investigation a maneuver which consisted of a 1 g lateral turn (L/W = 1.414) that crisscrossed a path parallel to the desired flight path was used. The target started to maneuver to the right or to the left at AI radar lock-on. The maximum deviation of target heading from this parallel flight path is 30°. This same basic maneuver is used in investigating the effect of target maneuver on missile miss distance and is detailed here.

Table XI gives a comparison of initial conditions for the pull-up attack investigation against maneuvering and nonmaneuvering targets. Those items relating to the nonmaneuvering targets are repeats of information presented previously on Table VIII. Several families were selected from those used in the nonmaneuvering target investigation and were employed in this phase. These families are listed in the first column of Table XI. The second column gives the fighter course which corresponds to the box in the probability grid from which the run originated. The third column gives the initial target aspect angle. The next ten columns give initial conditions of the fighter and target as follows: target altitude; fighter altitude at the start of pull-up; fighter altitude at missile launch; missile launch range; geometrical coordinates of range from interceptor to target at launch; azimuth and elevation steering errors at launch; and interceptor velocity. The final column on this table tells whether the target is flying straight and level (indicated by "none"), maneuvers initially to the left of his flight path, or maneuvers initially to the right of his flight path (maneuver starts at AI radar lock-on).

Table XII gives a comparison of Sparrow III miss distances when employed in pull-up attacks against nonmaneuvering targets and maneuvering targets. The initial conditions for each of these runs are given on Table XI. The first six columns of Table XII repeat some of these initial conditions. The same target noise is employed in this phase of the study as was used in the co-altitude and pull-up attacks detailed previously. Column seven lists the noise sample investigated. The next column gives the initial maneuver of the target (see description of Table XI). The next four columns give the components of miss at the target and the overall miss distance.

TABLE XI

COMPARISON OF INITIAL CONDITIONS AT MISSILE LAUNCH
FOR PULL-UP ATTACKS AGAINST NONMANEUVERING AND MANEUVERING TARGETS
B-47 Size Target V_T = M 2.0 $V_F = V_{max}$ at Pull-up

(1) Family Number	(2) Fighter Course	(3) Initial Target Aspect Angle τ_o (deg)	(4) Target Altitude H_T (ftx10^3)	(5) Fighter Altitude at Pull-up H_F (ftx10^3)	(6) Fighter Altitude at Launch Point (ftx10^3)	(7) Range Interlock Condition	Range from Target at Launch (8) R_X (ft)	(9) R_Y (ft)	(10) R_Z (ft)	Steering Error at Launch (11) AZ ϵ_a (deg)	(12) EL ϵ_e (deg)	(13) Fighter Velocity V_F (ft/sec)	(14) Initial Target Maneuver
4	C-5	0	65	50	56.301	R_{max}	34540	10650	-8699	-0.011	0.074	1658	None
4	C-5	0	65	50	56.137	R_{max}	32180	14180	-8863	11.604	3.677	1596	Left
7	D-4	0	75	50	59.564	R_{max}	33430	3717	-15440	0.691	6.894	1528	None
7	D-4	0	75	50	58.956	R_{max}	33880	7874	-16040	4.311	17.114	1539	Left
16	E-1	45	65	50	54.63	R_{max}	26760	24500	-10370	-0.024	0.227	1738	None
16	E-1	45	65	50	55.298	R_{max}	24440	19880	-9702	-5.319	7.667	1693	Right
27	D-1	45	75	50	57.671	R_{max}	17550	28040	-17330	-0.489	0.828	1604	None
27	D-1	45	75	50	58.722	R_{max}	15230	22080	-16280	-7.438	8.858	1564	Right

TABLE XII

COMPARISON OF SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
AGAINST NONMANEUVERING AND MANEUVERING TARGETS
B-47 Size Target V_T = M 2.0 V_F = V_{max} at Pull-up

(1) Family Number	(2) Fighter Course	(3) Initial Target Aspect Angle τ_o (deg)	(4) Target Altitude H_T (ftx10³)	(5) Fighter Altitude at Pull-up H_F (ftx10³)	(6) Range Interlock Condition	(7) Noise Sample	(8) Initial Target Maneuver	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Distance R_{MT} (ft)
4	C-5	0	65	50	R_{max}	1	None	-21.8	36.9	-12.1	44.5
							Left	-45.3	70.5	-19.6	86.0
						2	None	5.4	21.7	45.1	50.3
							Left	-42.0	78.6	12.1	90.0
						3	None	-87.3	127.8	-50.6	162.8
							Left	-47.2	66.4	-31.2	87.2
						4	None	-49.1	63.0	17.1	81.7
							Left	-35.0	58.1	-6.8	68.2
						5	None	-53.4	71.5	-50.1	102.3
							Left	-30.4	47.0	-10.3	56.9
						6	None	-23.0	36.6	-18.6	47.1
							Left	-35.5	48.3	-25.9	65.3
						7	None	-76.2	47.7	-80.4	120.7
							Left	-39.9	67.8	-6.4	78.9
						8	None	-25.7	-24.6	-10.6	37.1
							Left	-48.7	103.4	28.7	117.8
						9	None	-17.1	38.3	-15.6	44.7
							Left	-43.5	79.1	-1.2	90.3

TABLE XII
COMPARISON OF SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
AGAINST NONMANEUVERING AND MANEUVERING TARGETS
B-47 Size Target V_T = M 2.0 V_F = V_{max} at Pull-up

(1) Family Number	(2) Fighter Course	(3) Initial Target Aspect Angle τ_o (deg)	(4) Target Altitude H_T (ftx10^3)	(5) Fighter Altitude at Pull-up H_F (ftx10^3)	(6) Range Interlock Condition	(7) Noise Sample	(8) Initial Target Maneuver	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Distance R_{MT} (ft)
						10	None	4.9	4.3	17.5	18.7
							Left	-36.4	60.7	-4.5	70.9
					Mean	=	None				71.0
							Left				81.2
					σ	=	None				42.7
							Left				16.1
					No Noise =		None				4.7
							Left				58.2
7	D-4	0	75	50	R_{max}	1	None	-31.9	76.8	-43.2	93.7
							Left	-339.3	963.9	-167.1	1035.5
					No Noise =		None				25.7
							Left				1028.4
16	E-1	45	65	50	R_{max}	1	None	-3.4	11.0	15.4	19.3
							Right	-3.9	-5.8	-21.6	22.7
						2	None	2.7	-23.6	-37.9	44.8
							Right	-38.8	25.5	-42.0	62.6

TABLE XII

COMPARISON OF SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS AGAINST NONMANEUVERING AND MANEUVERING TARGETS

B-47 Size Target V_T = M 2.0 V_F = V_{max} at Pull-up

(1) Family Number	(2) Fighter Course	(3) Initial Target Aspect Angle τ_o (deg)	(4) Target Altitude H_T (ftx10^3)	(5) Fighter Altitude at Pull-up H_F (ftx10^3)	(6) Range Interlock Condition	(7) Noise Sample	(8) Initial Target Maneuver	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Distance R_{MT} (ft)
						3	None	-3.8	0.5	-12.3	12.8
							Right	-60.4	53.3	-47.1	93.3
						4	None	-33.5	-15.1	-54.8	65.5
							Right	-58.1	80.8	21.5	101.8
						5	None	-4.7	2.0	4.8	7.0
							Right	-0.9	-21.8	-45.8	50.7
						6	None	-6.4	2.5	3.8	7.9
							Right	-47.3	15.7	-74.6	89.7
						7	None	-20.1	13.1	56.3	61.2
							Right	-5.3	-52.7	-116.3	127.8
						8	None	-36.8	32.8	8.4	50.0
							Right	-17.7	42.1	40.0	60.7
						9	None	-13.0	12.2	-1.9	17.9
							Right	-13.9	21.7	7.9	27.0

TABLE XII
COMPARISON OF SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
AGAINST NONMANEUVERING AND MANEUVERING TARGETS
B-47 Size Target V_T = M 2.0 V_F = V_{max} at Pull-up

(1) Family Number	(2) Fighter Course	(3) Initial Target Aspect Angle τ_o (deg)	(4) Target Altitude H_T (ftx10^3)	(5) Fighter Altitude at Pull-up H_F (ftx10^3)	(6) Range Interlock Condition	(7) Noise Sample	(8) Initial Target Maneuver	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Distance R_{MT} (ft)
						10	None	-18.4	19.5	6.7	27.6
							Right	-21.2	39.8	25.9	51.5
					Mean =		None				31.4
							Right				68.8
					σ =		None				21.0
							Right				31.9
					No Noise =		None				9.6
							Right				28.8
27	D-1	45	75	50	R_{max}	1	None	-63.6	18.6	-34.3	74.7
							Right	34.4	-132.5	-137.1	193.8
						2	None	-98.7	35.8	-45.0	114.2
							Right	35.3	-184.6	-202.8	276.5
						3	None	-50.6	15.4	-26.8	59.3
							Right	31.4	-128.8	-133.3	188.0

TABLE XII
COMPARISON OF SPARROW III 6a MISS DISTANCES - PULL-UP ATTACKS
AGAINST NONMANEUVERING AND MANEUVERING TARGETS
B-47 Size Target V_T = M 2.0 $V_F = V_{max}$ at Pull-up

(1) Family Number	(2) Fighter Course	(3) Initial Target Aspect Angle τ_o (deg)	(4) Target Altitude H_T (ftx10³)	(5) Fighter Altitude at Pull-up H_F (ftx10³)	(6) Range Interlock Condition	(7) Noise Sample	(8) Initial Target Maneuver	Miss Distance at Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Distance R_{MT} (ft)
						4	None	-83.4	22.1	-54.2	101.9
							Right	15.8	-98.6	46.6	-108.9
						5	None	-160.7	46.6	-103.9	196.9
							Right	5.1	-86.6	-106.5	137.3
					Mean	=	None				109.4
							Right				188.7
					σ	=	None				47.8
							Right				49.1
					No Noise	=	None				56.7
							Right				168.5

The misses given for the nonmaneuvering case, labeled "none", are the same as those given previously on Table IX. There is one exception in Family 27, where the probability of passing within 25 ft CG to CG is different from that given for the same family on Table X. This is because a different number of noise samples are examined. At the end of each family (for example, Family 4), the mean miss distance, standard deviation of miss, and no noise miss distances, are given for all families investigated where five or more noise samples were examined (all except Family 7).

The results given on Table XII are converted to miss distance probabilities on Table XIII. Only three of the four families given on Table XII are repeated here since only one noise sample was used for Family 7. The first seven columns are a repeat of information given on Table XII. Column eight gives the resulting mean miss distances in feet. Standard deviation of the miss is shown in column nine. Column ten gives the percentage of runs observed to pass within 25 ft CG to CG of the target. In each case examined, target maneuver reduced the percent success. For example, the results of Family 16 is reduced from 50% for no target maneuver to 8.8% for target maneuver. The eleventh column compares the results obtained by observing the percentage of runs which placed the missile within 10 ft S to S. Again the results are very low. The twelfth column gives the results when either miss criteria is satisfied.

REMAINING STUDY EFFORT

The details given in this report describe the first part of the concluding phase of the Navy's Air to Air Missile Study as related to the system employing the Sparrow III 6a. It is anticipated that five additional reports will be issued on the results of this study. The first will show the results of parameter variation about the values given in this report for the unimproved Sparrow III 6a. The second will give miss distance results for the improved (current) Sparrow III 6a. The third will detail the simulation techniques used in the pull-up attack investigation. The fourth will detail parameter variations encountered in the missile simulation, and the fifth will be a formal report summarizing the results obtained in the entire study of the system employing the Sparrow III 6a. There will be a continuing effort directed toward employing the results in the developing and testing of the system. Where applicable, memorandum reports will be issued detailing this effort.

TABLE XIII
COMPARISON OF MISS DISTANCE RESULTS - PULL-UP ATTACK AGAINST NONMANEUVERING AND MANEUVERING TARGETS

B-47 Size Target V_T = M 2.0 $V_F = V_{max}$ at Pull-up

(1) Family Number	(2) Fighter Course	(3) Initial Target Aspect Angle τ_c (deg)	(4) Target Altitude H_T (ftx10^3)	(5) Fighter Altitude at Pull-up H_F (ftx10^3)	(6) Range Interlock Condition	(7) Initial Target Maneuver	(8) Mean Miss (ft)	(9) Standard Deviation σ (ft)	(10) Runs Within 25 ft CG to CG (%)	(11) Runs Within 10 ft S to S (%)	(12) Runs That Satisfy Either Criteria (%)
4	C-5	0	65	50	R_{max}	None	71.0	42.7	10	0	10
						Left	81.2	16.1	0	0	0
16	E-1	45	65	50	R_{max}	None	31.4	21.0	50	40	50
						Right	68.8	31.9	8.8	10	20
27	D-1	45	75	50	R_{max}	None	109.4	47.8	0	0	0
						Right	188.7	49.1	0	0	0

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations presented here in no way void those given previously in other volumes of this series. Data in this volume is an extension of that given previously, and emphasis is placed on the missile launch and guidance phases. Because of the large number of tactical problems investigated and because of the complexity of each, the reader is encouraged to refer to the text, especially the tables, for the full meaning of the general conclusions and recommendations which follow.

I. Co-Altitude Attack Investigation

The unimproved Sparrow III missile which was then known (at the time of simulation effort) as the Sparrow III 6a was simulated along with the current version of the F4H-1 aircraft and the AN/APQ-72 radar. During this study phase, changes have occurred in the Sparrow III. Thus, this version is labeled as unimproved Sparrow III 6a and corresponds to the missile whose $V_o = 800\left[1+0.41(1-P/P_{SL})\right]$. When this combination is used the following conclusions on Sparrow III miss distances apply:

(a) For target aspect angle of 15° off the target's nose and R_{max} co-altitude launch conditions from intercept runs which constitute a successful conversion to missile launch against a M 2.0, B-47 size target at 50,000 ft, the percentage of missiles which were observed to pass within 25 ft CG to CG of the target varied between 40% and 60% (see Table VI).

(b) When the launch range is reduced to R_{min} and all other conditions are the same as item (a), the percentage of missiles which were observed to pass within 25 ft CG to CG of the target varied between 30% and 50% (see Table VI).

(c) When a lethality criterion of 25 ft CG to CG or 10 ft S to S with respect to the target are applied to the missile launches made under the conditions of item (a), the percentage of missile runs which satisfied these criteria varied between 50% and 80% (see Table VI).

(d) When the 25 ft CG to CG or 10 ft S to S criterion is applied to missile launches from the same conditions as item (b), the percentage of missile runs which satisfied these criteria varied between 40% and 70% (see Table VI).

II. Pull-up Attack Investigation

The "unimproved" Sparrow III missile as described for the co-altitude case was employed in pull-up attacks. When this missile is launched in pull-up attacks from intercept runs which constitute a successful conversion to missile launch, the following results are obtained:

(a) When pull-up attack missile launches are made from intercepts initiated head-on against a nonmaneuvering M 2.0 target flying at 65,000 ft altitude, the percentage of missiles which passed within 25 ft CG to CG of the target varied from 0% to 20% (see Table X).

(b) For the same conditions as item (a), except that the target altitude is increased to 75,000 ft (5000 ft above specification altitude), the percentage of missiles which passed within 25 ft CG to CG of the target was 0% (see Table X).

(c) When pull-up attack missile launches are made from intercepts which initiate from 45° off the target's nose against a nonmaneuvering M 2.0 target flying at 65,000 ft altitude, the percentage of missiles which passed within 25 ft CG to CG of the target varied from 0% to 50% for R_{max} launches; from 0% to 10% for $(R_{max}+R_{min})/2$ launches; and 0% for R_{min} launches (see Table X).

(d) For the same conditions as those if item (c), except that the target altitude is increased to 75,000 ft, the probability that the missile will pass within 25 ft CG to CG of the target was 0% for all launch ranges investigated (see Table X).

(e) When the lethality criterion of 25 ft CG to CG or 10 ft S to S is applied to the missile launches described under items (a) thru (d), the results are still very low and the percentage varies from 0% to 50% for all conditions investigated (see Table X).

(f) In pull-up attacks against a M 2.0 target flying at 65,000 ft or 75,000 ft altitude, initiating a simple 1 g crisscross maneuver at AI radar lock-on, the percentage of missiles which passed within 25 ft CG to CG are very low. For example, when the pull-up is head-on from 50,000 ft altitude and the missile is launched at R_{max} the percentage of missiles passing within 25 ft CG to CG is 0%. All other cases investigated yielded consistently low results (see Table XIII).

(g) When the lethality criterion of 25 ft CG to CG or 10 ft S to S is applied to missile launches against high altitude maneuvering targets, the results are still low. The percentages obtained varied from 0% to 20% (see Table XIII).

ACKNOWLEDGEMENTS

The data presented in this report embodies results, to date, of the Navy's Air to Air Missile Study Program. The analytical results, including those from which the figures were derived, were acquired through the computational work underway at Westinghouse Air Arm Division. A large portion of the data reduction required for the material within in this volume was actually accomplished at Westinghouse, and reviewed for accuracy by the Technical Directors. In addition, results of analyses underway at the Naval Missile Center, Pt. Mugu are included. The data used to define the Sparrow III missile and the AN/APA-128 computer were obtained from The Raytheon Company. Definition of the aircraft performance was obtained from the McDonnell Aircraft Company. Test data on AI radar performance was supplied by the Naval Air Test Center, Patuxent River. The authors wish to extend their appreciation to members of these activities for their cooperation.

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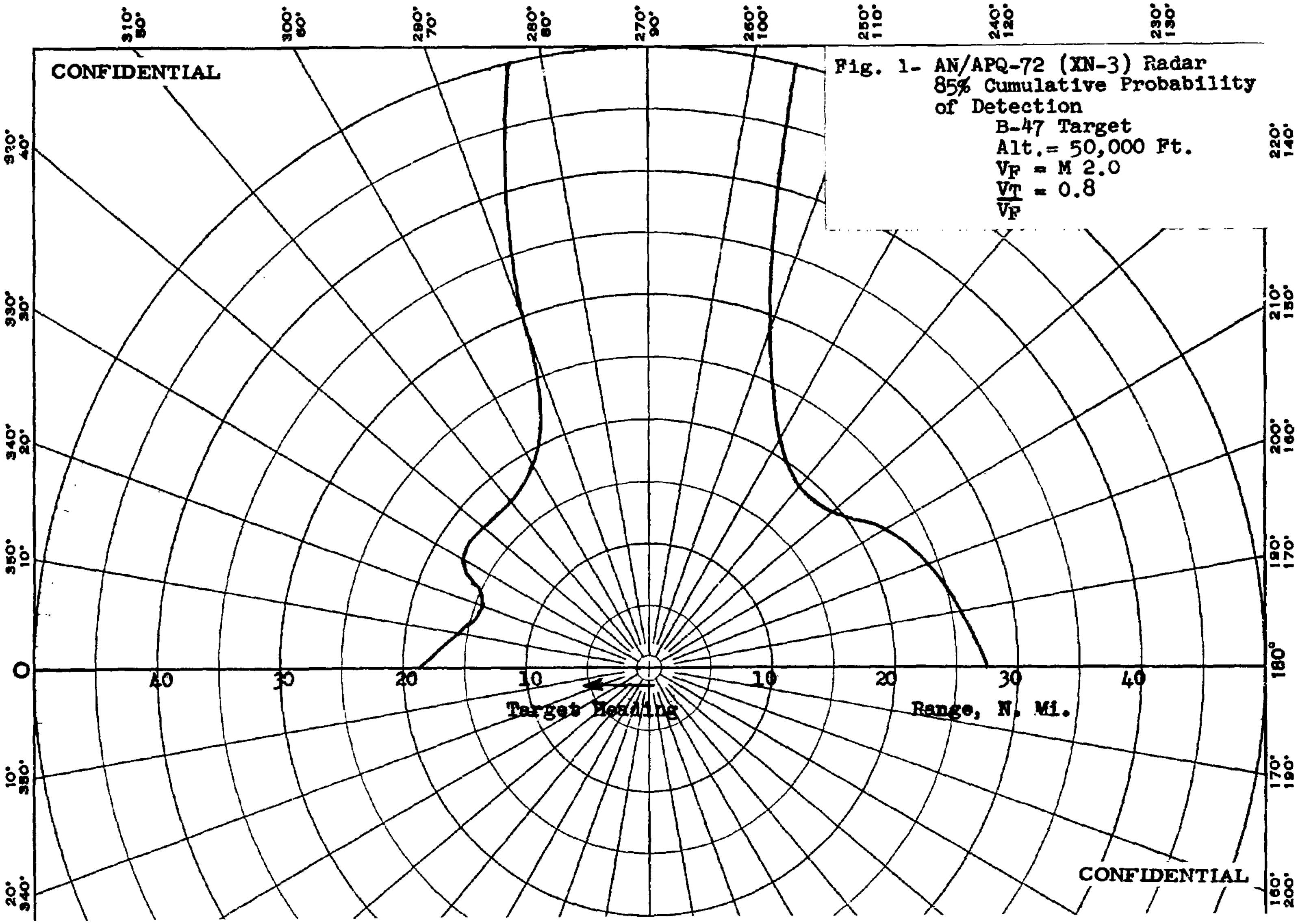

Fig. 1- AN/APQ-72 (XN-3) Radar
85% Cumulative Probability
of Detection
B-47 Target
Alt.= 50,000 Ft.
V_F = M 2.0
$\frac{V_T}{V_F}$ = 0.8

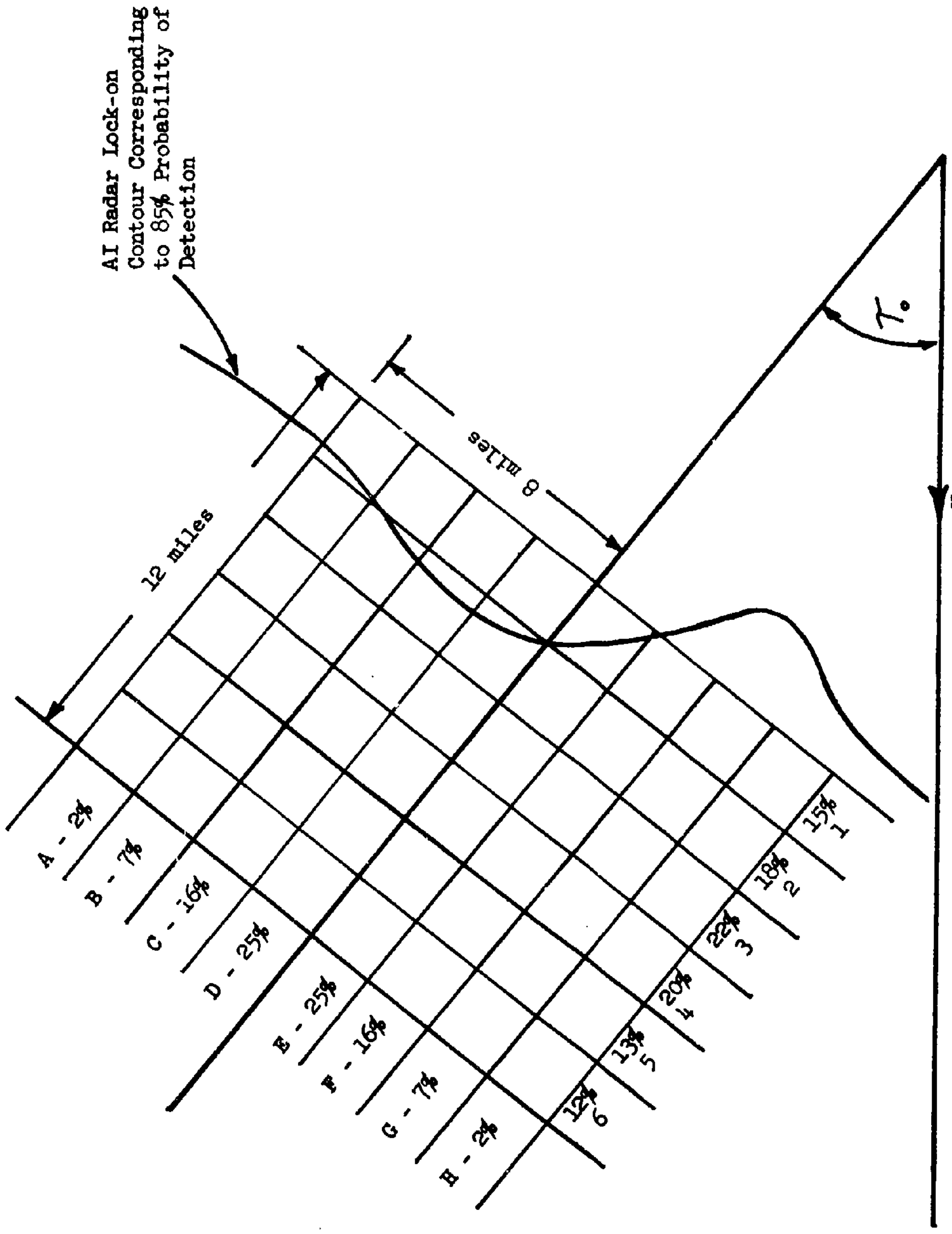

Fig. 2 - Probability Grid from which Intercepts Originate

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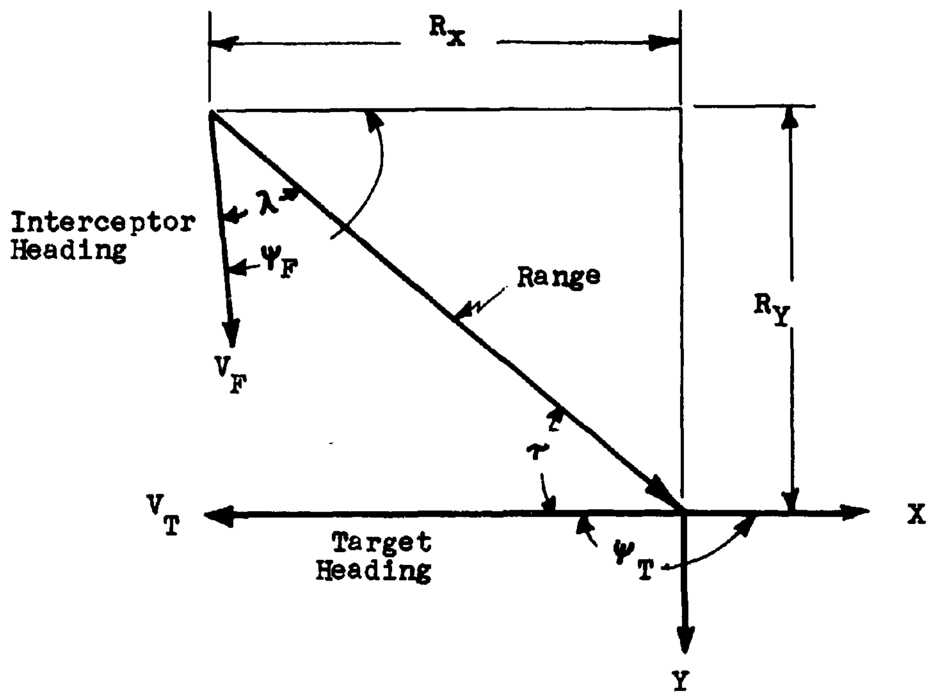

R = Range Vector
X,Y,Z = Reference Axes
R_X, R_Y, R_Z = Components of Range Along X,Y,Z (Z-Axis Positive Downward)
τ = Angle off the Target Nose
ψ_F = Eulerian Angle of Fighter Velocity Vector in Azimuth
V_F = Fighter Velocity Vector
V_T = Target Velocity Vector
λ = Lead Angle

Fig. 3- Attack Geometry

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Fig-4a- Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$\tau_o = 15°$, R_{Max} Launch, Fighter Course - B-3

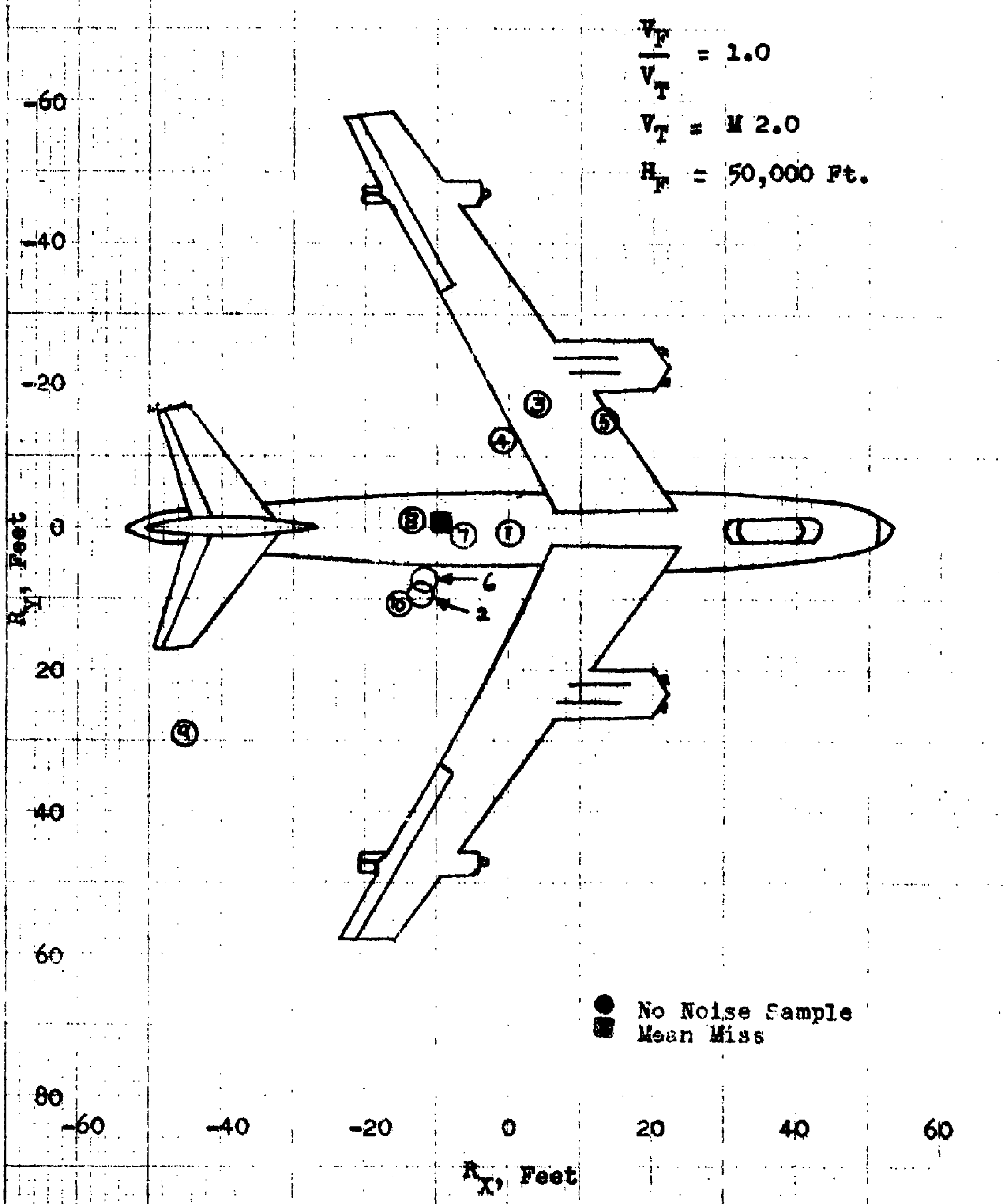

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Fig. 4b- Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
$\tau_0 = 15^\circ$, R_{Max} Launch, Fighter Course - B-3

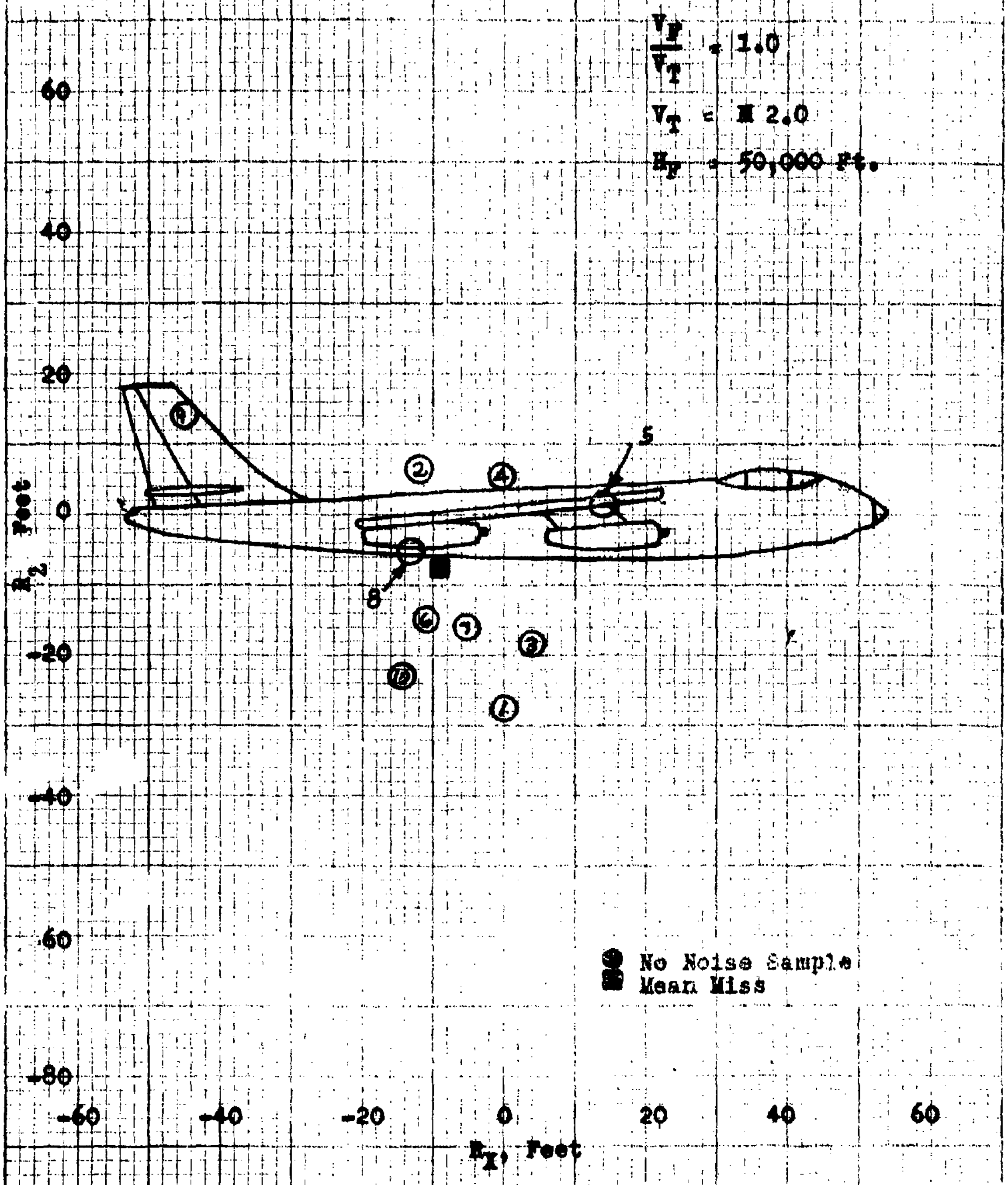

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Fig. 4c- Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
Γ_o = 15°, R_{Max} Launch, Fighter Course - B-3

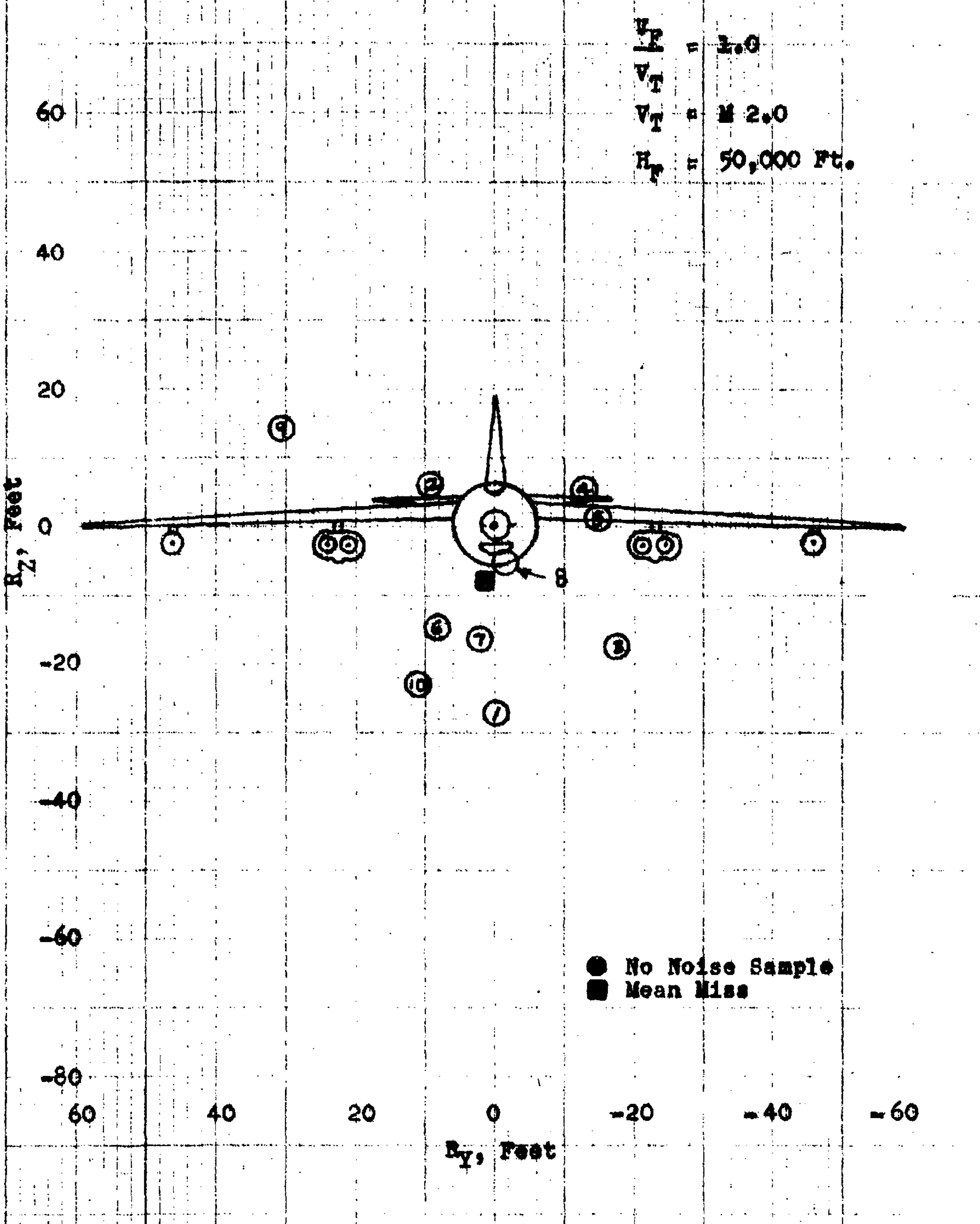

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Fig. 5a- Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$T_o = 15°$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course - B-3

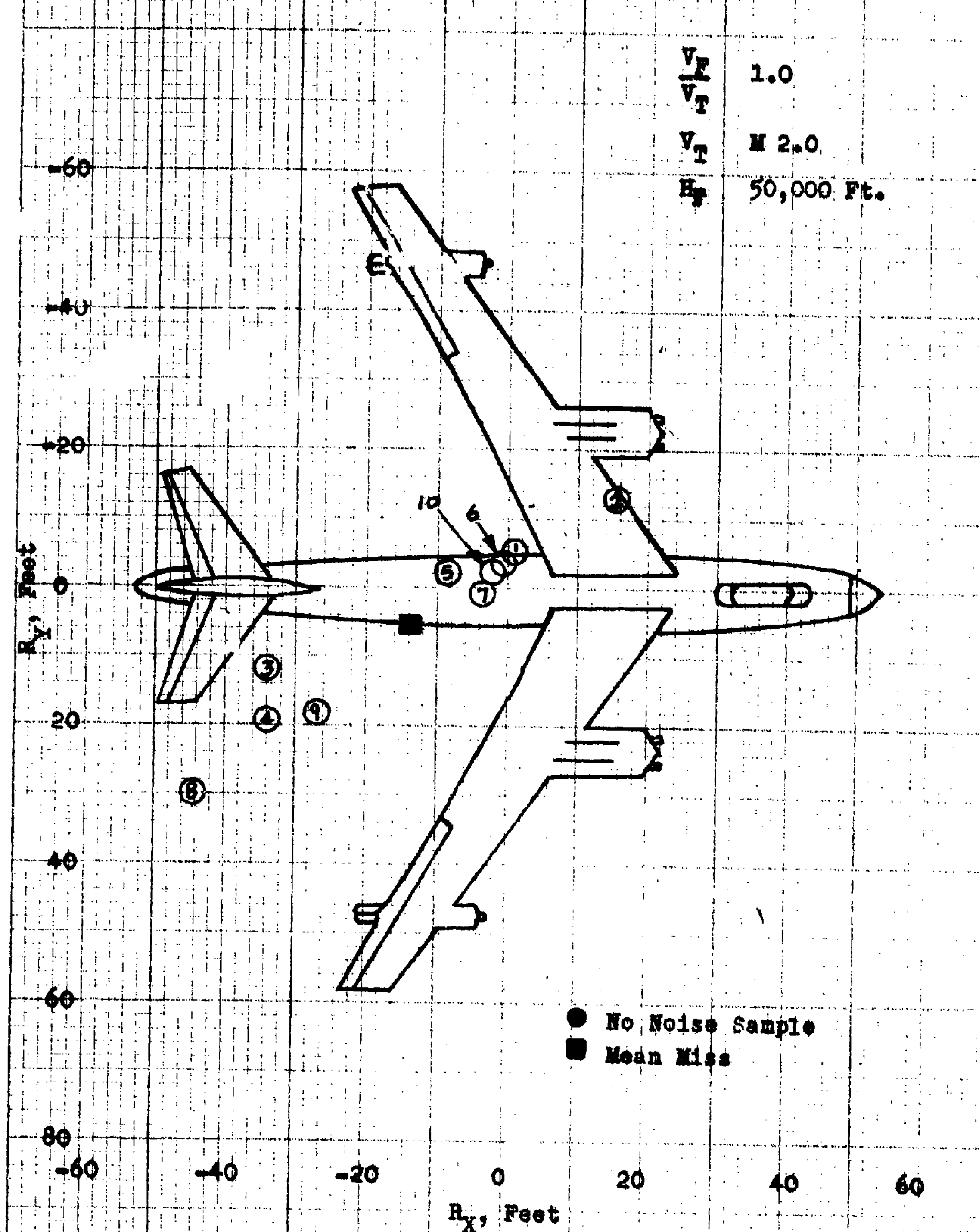

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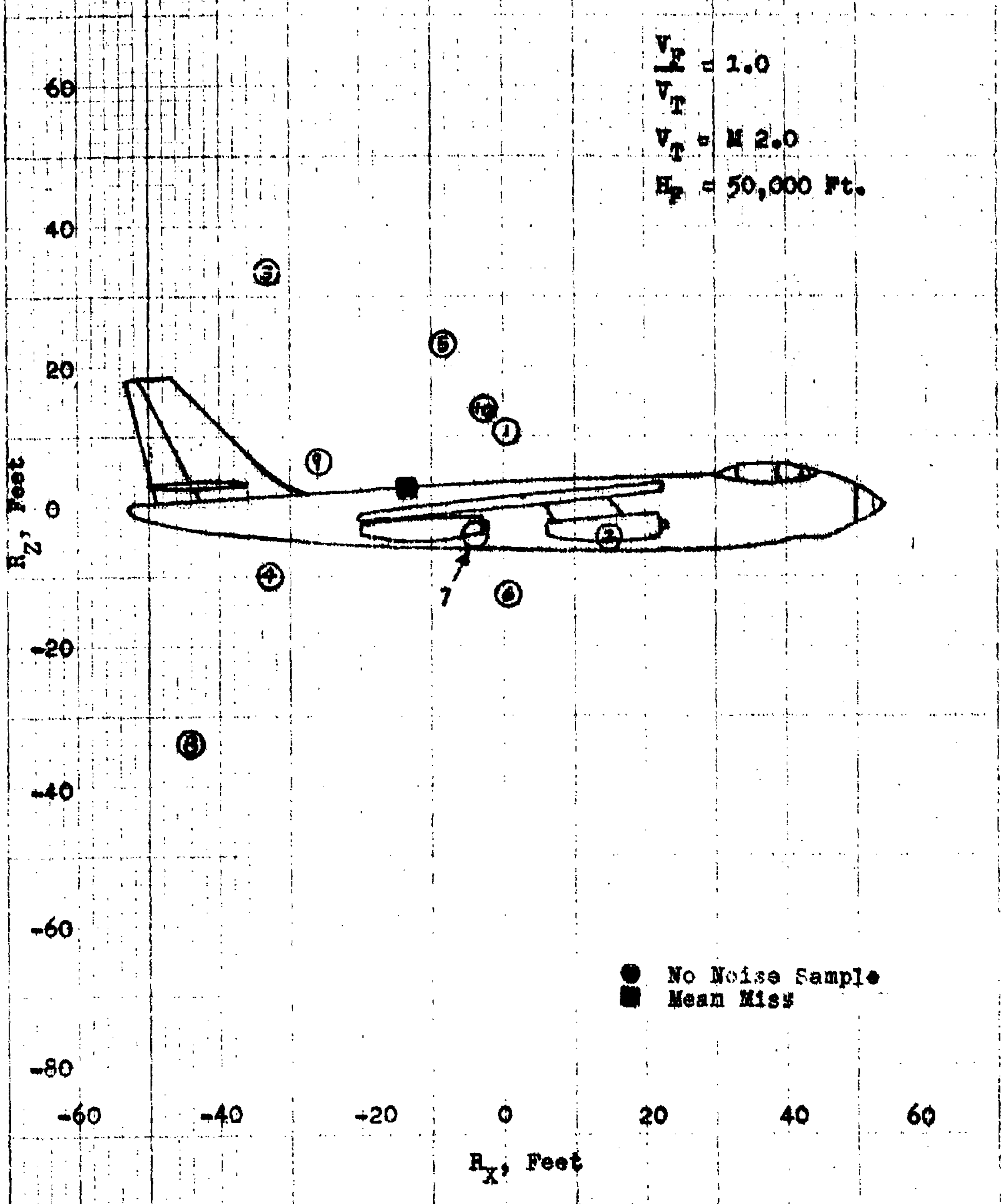
Fig. 5b- Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
$\tau_s = 15^\circ$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course - B-3



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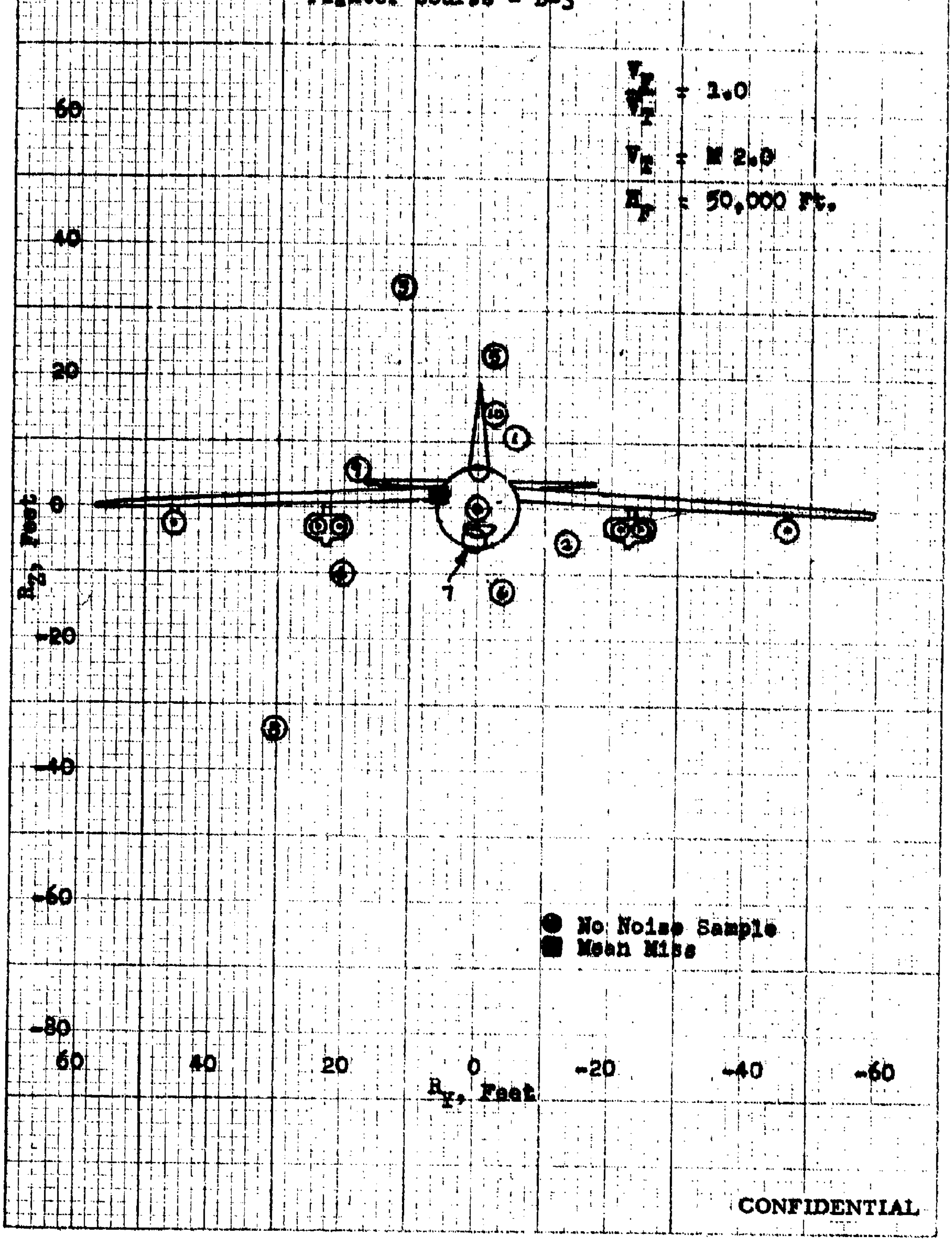

Fig. 5e - Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
T_o = 15°, ½(R_{Max} + R_{Min}) Launch
Fighter Course - B-3

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Fig. 6a- Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$\Psi_o = 15^o$, R_{Min} Launch, Fighter Course - B-3

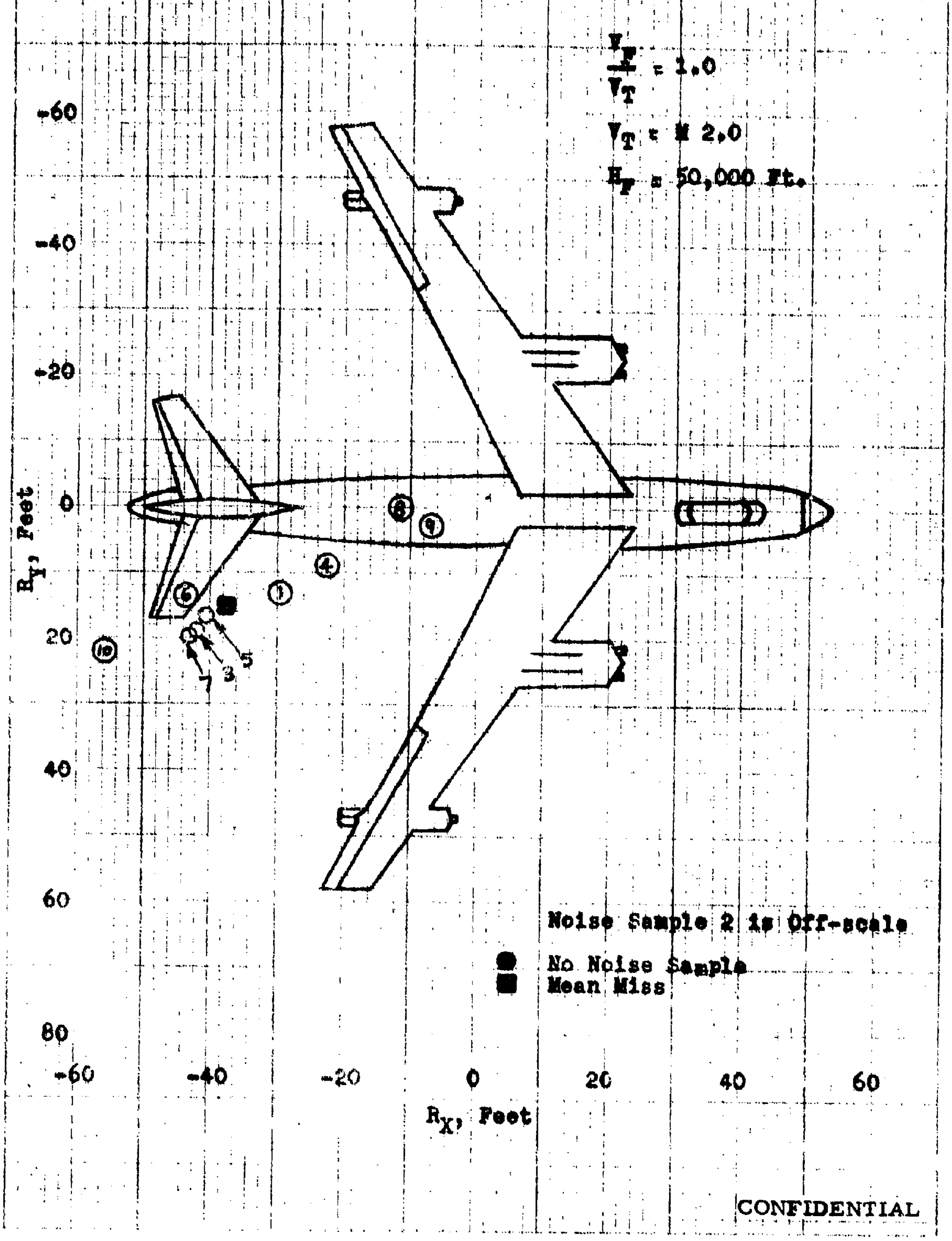

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FIG. 6[illegible]- Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
$\tau_D = 15^\circ$, R_{Min} Launch, Fighter Course - B-3

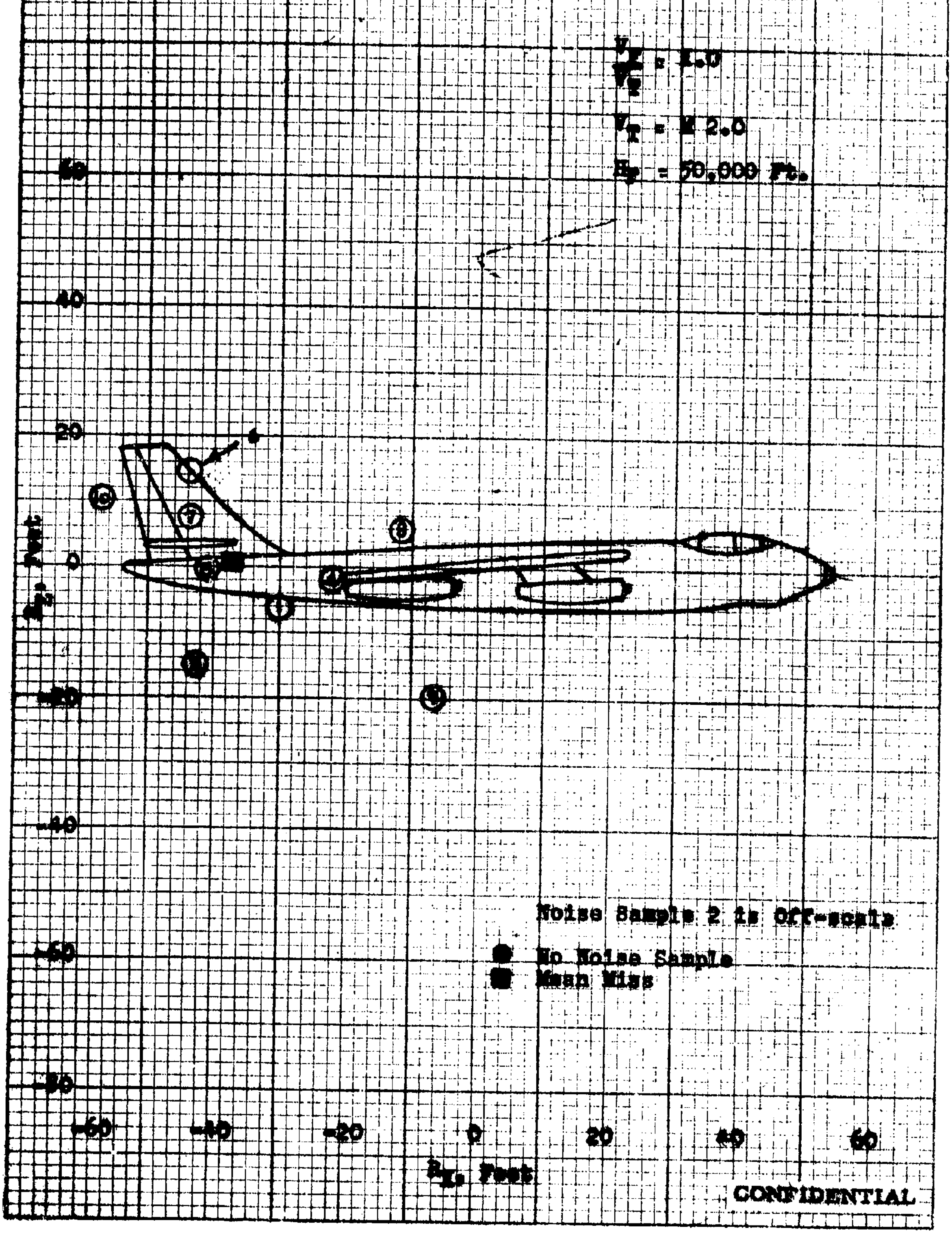

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Fig. 6c- Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
$\tau_o = 15^\circ$, R_{Min} Launch, Fighter Course - B-3

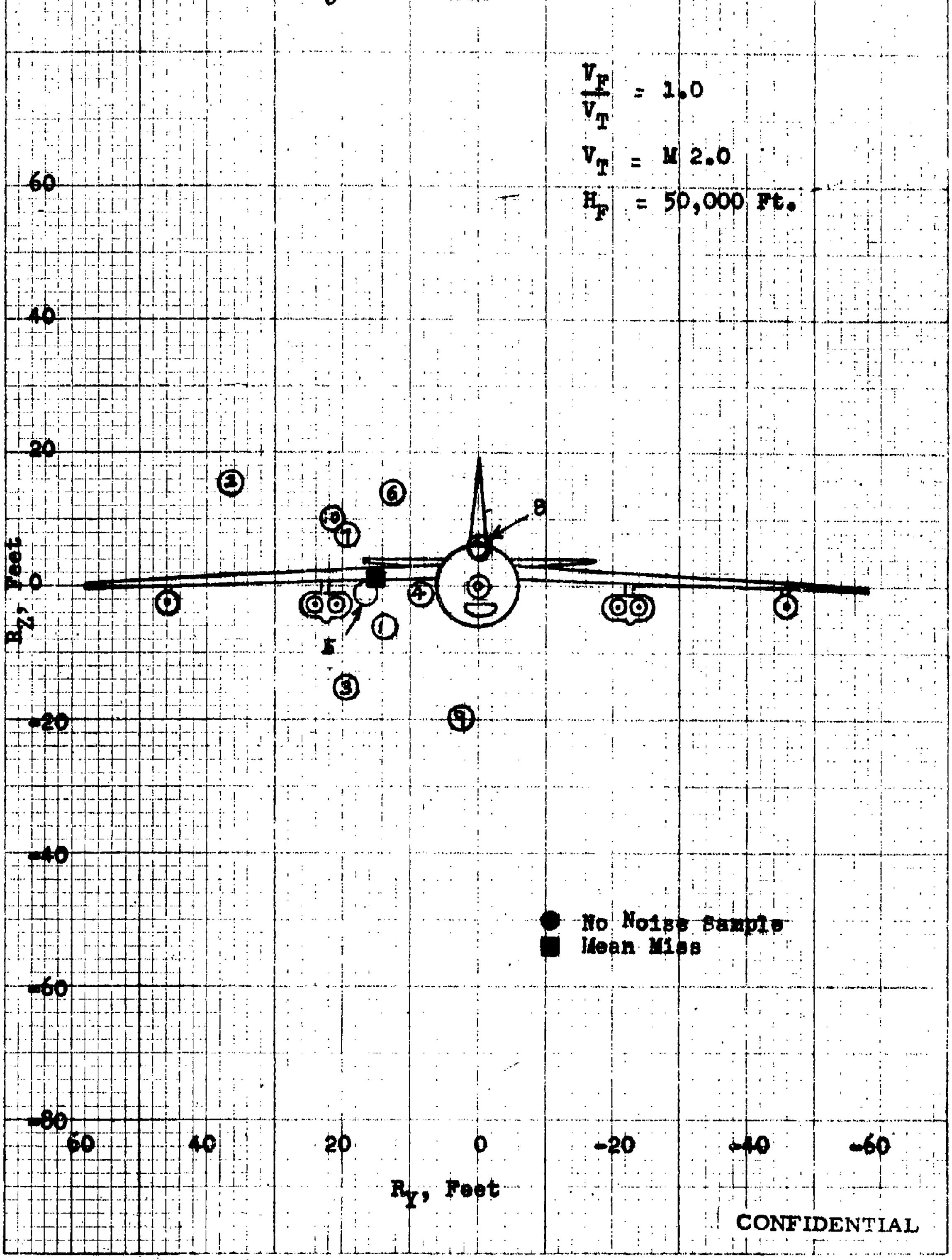

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Fig. 7a - Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$\tau_D = 15°$, $R_{Max\ Launch}$, Fighter Course - D-1

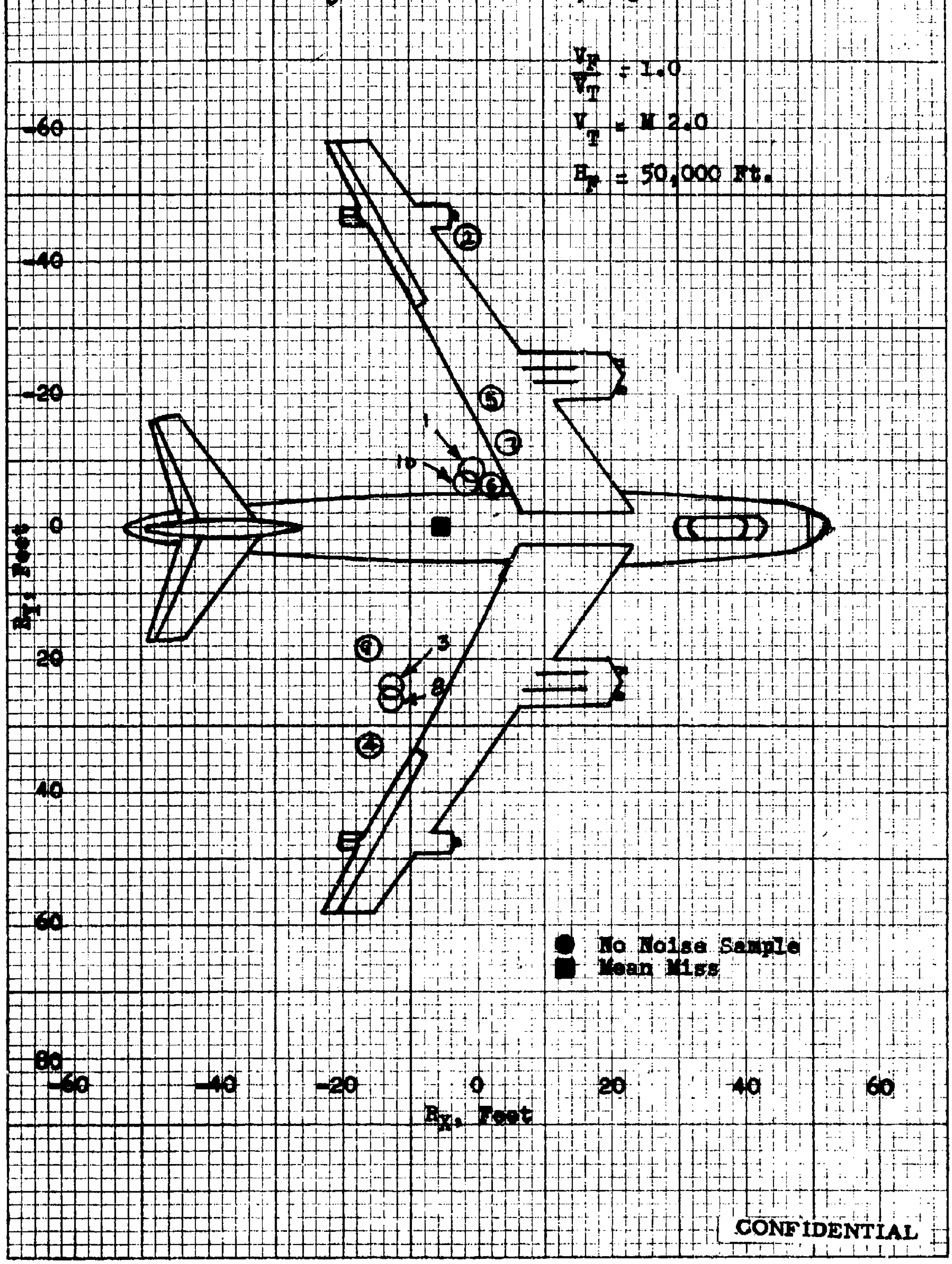

Fig. 7b- Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
$\tau_0 = 15°$, R_{Max} Launch, Fighter Course - D-1

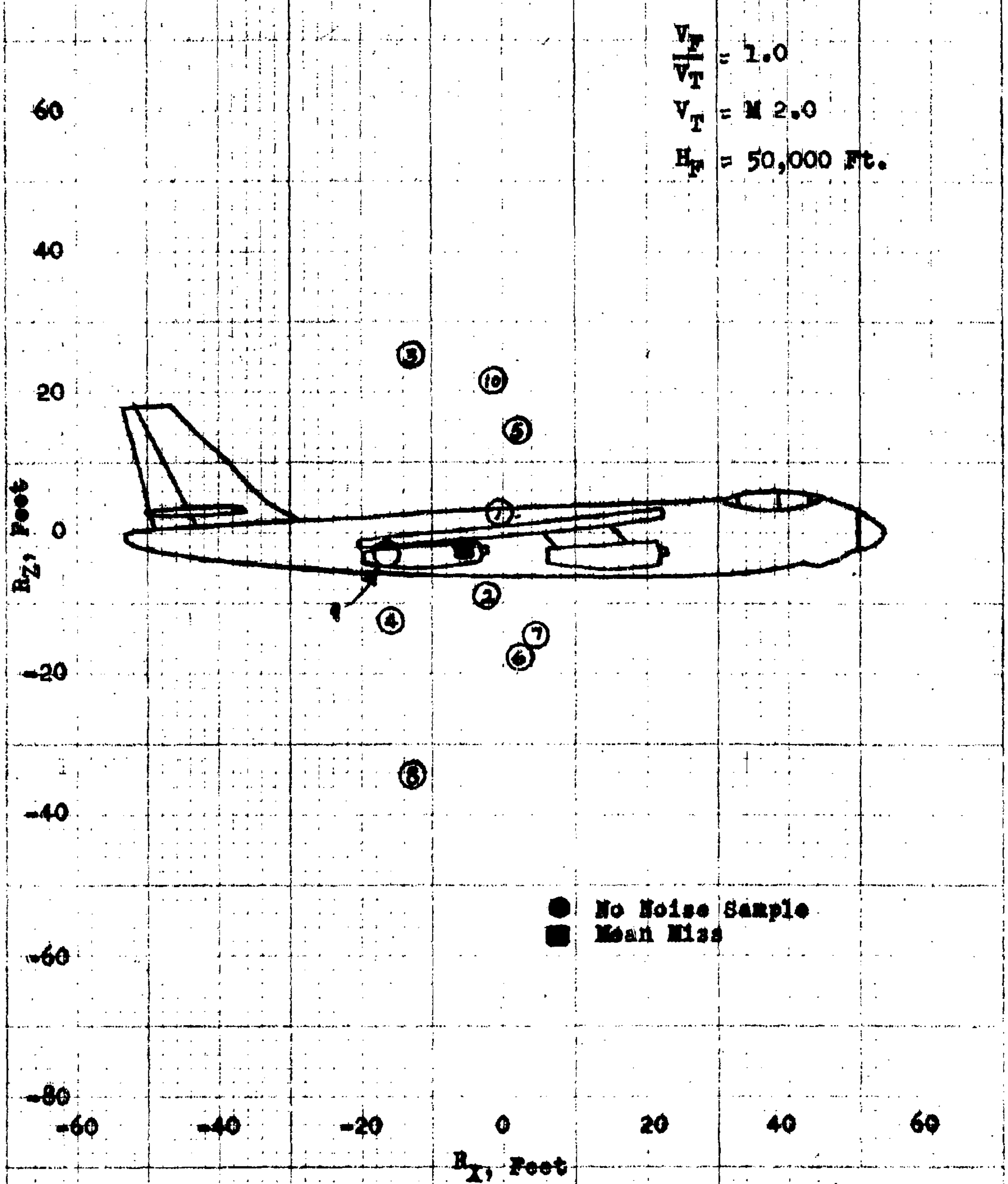

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Fig. 7c- Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
$\tau_o = 15^\circ$, R_{Max} Launch, Fighter Course - D-1

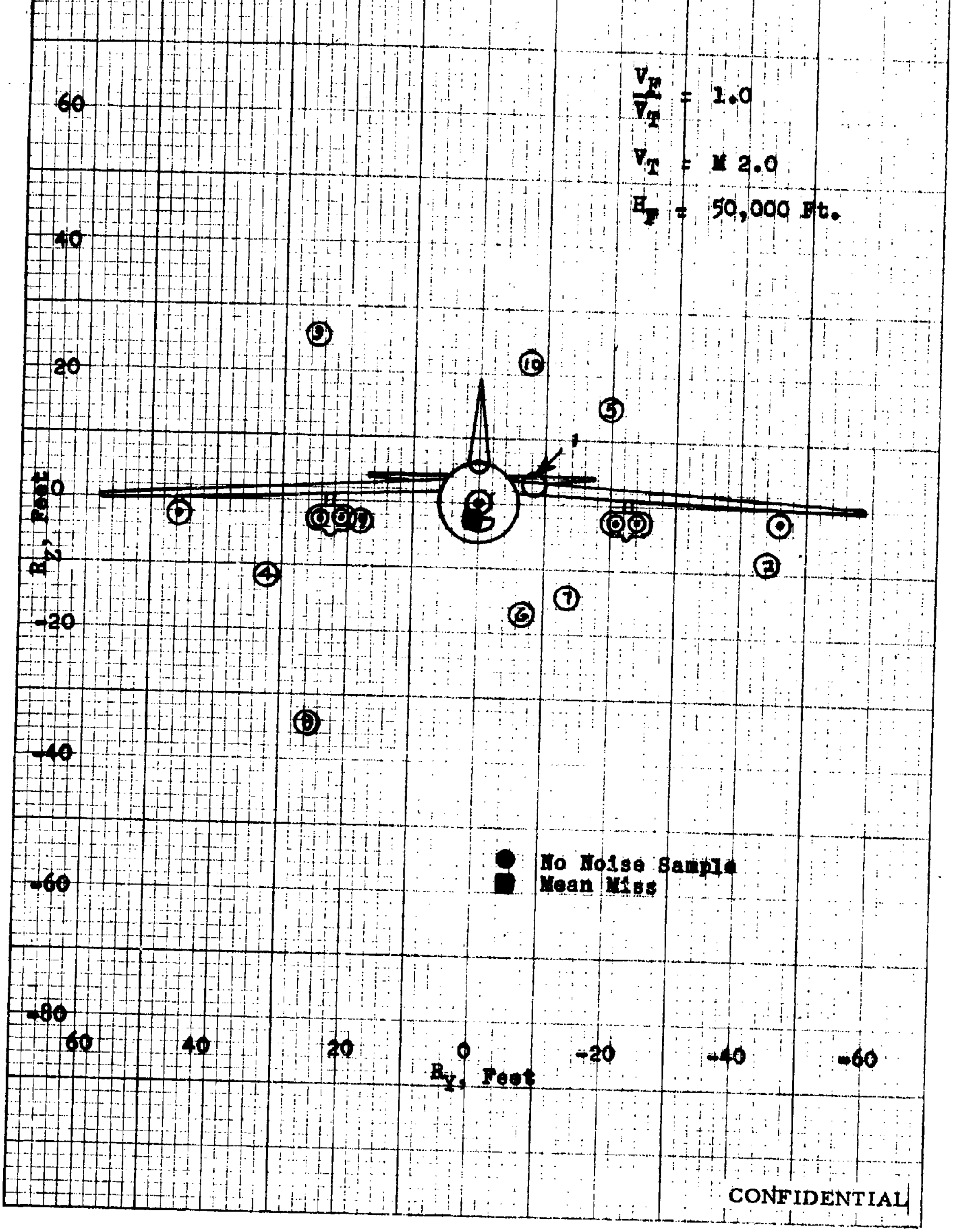

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Fig. 8a- Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$\tau_o = 15°$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course - D-1

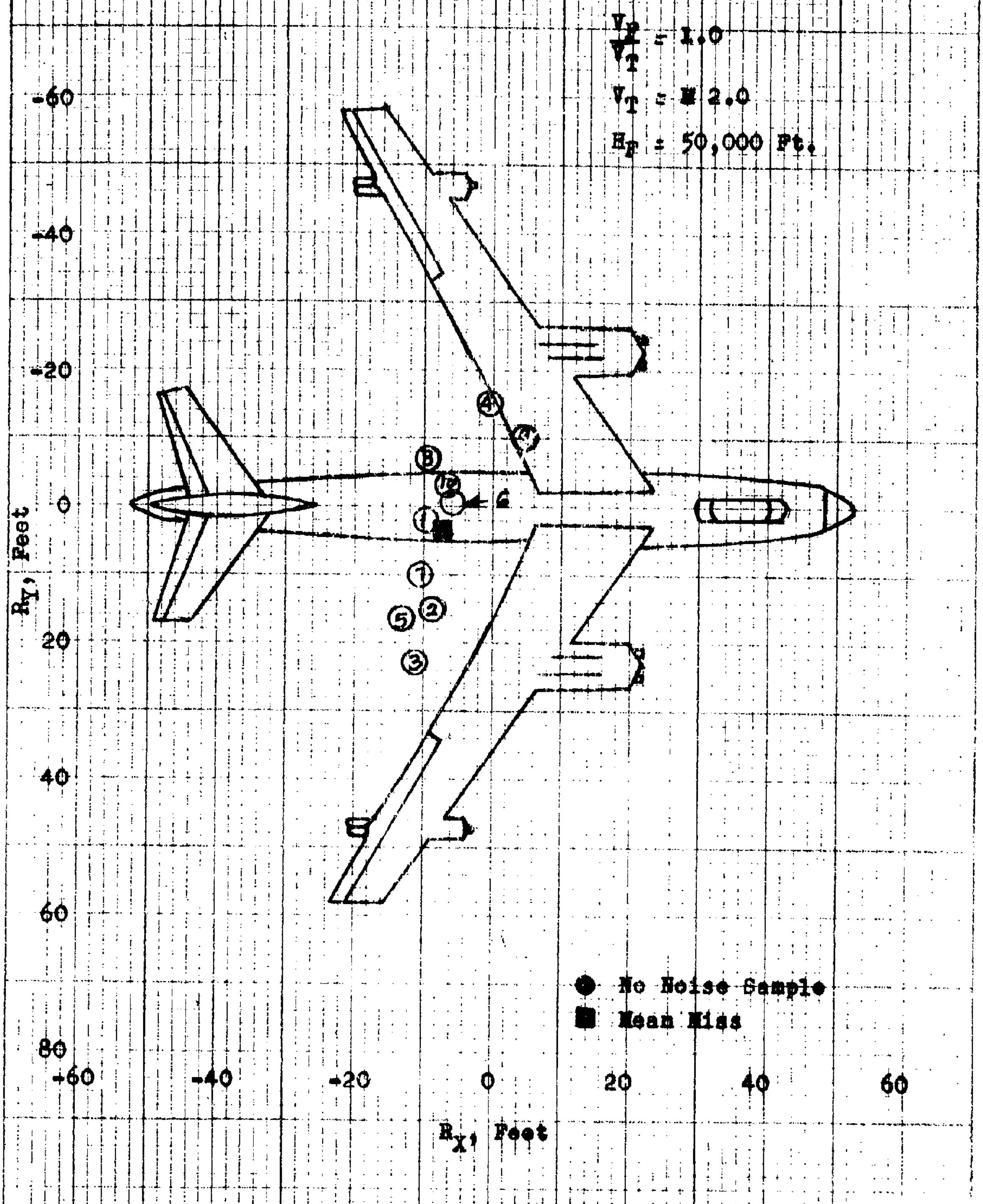

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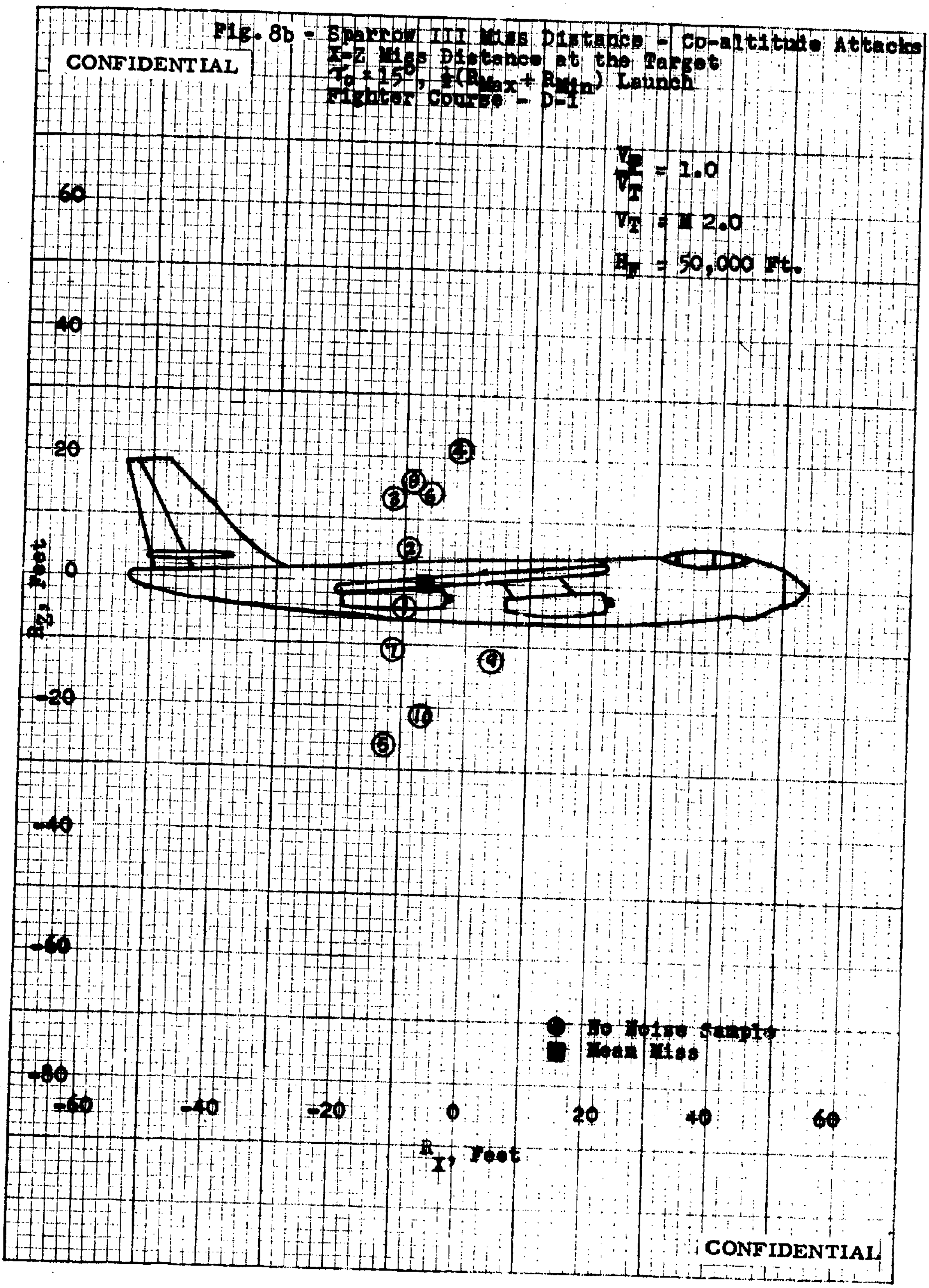
Fig. 8b - Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
$\gamma_0 = 15^\circ$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course - D-1



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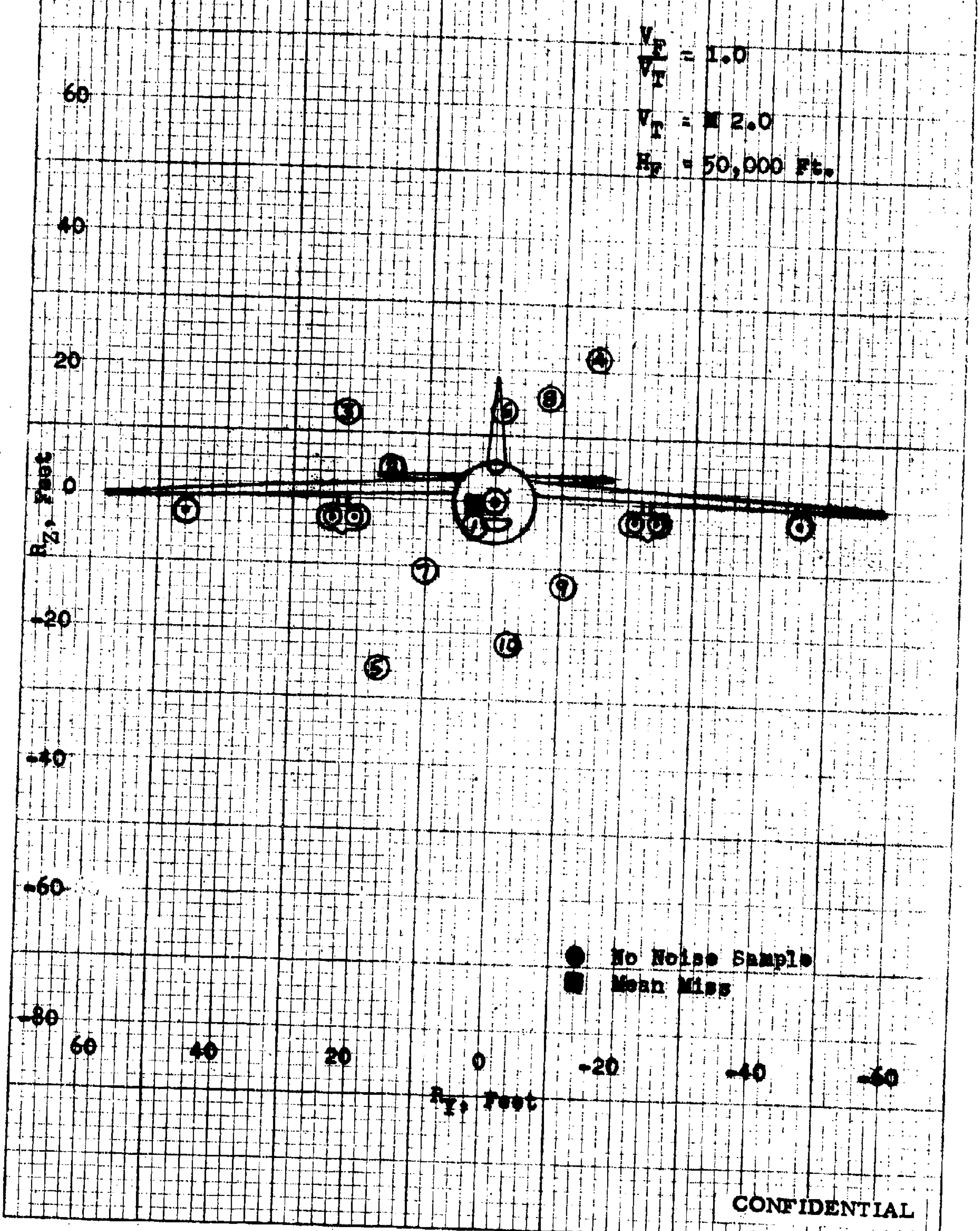

Fig. 8c- Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
$\gamma_s = 15^\circ$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course - D-1

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Fig. 9a- Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$\tau_o = 15°$, R_{Min} Launch, Fighter Course - D-1

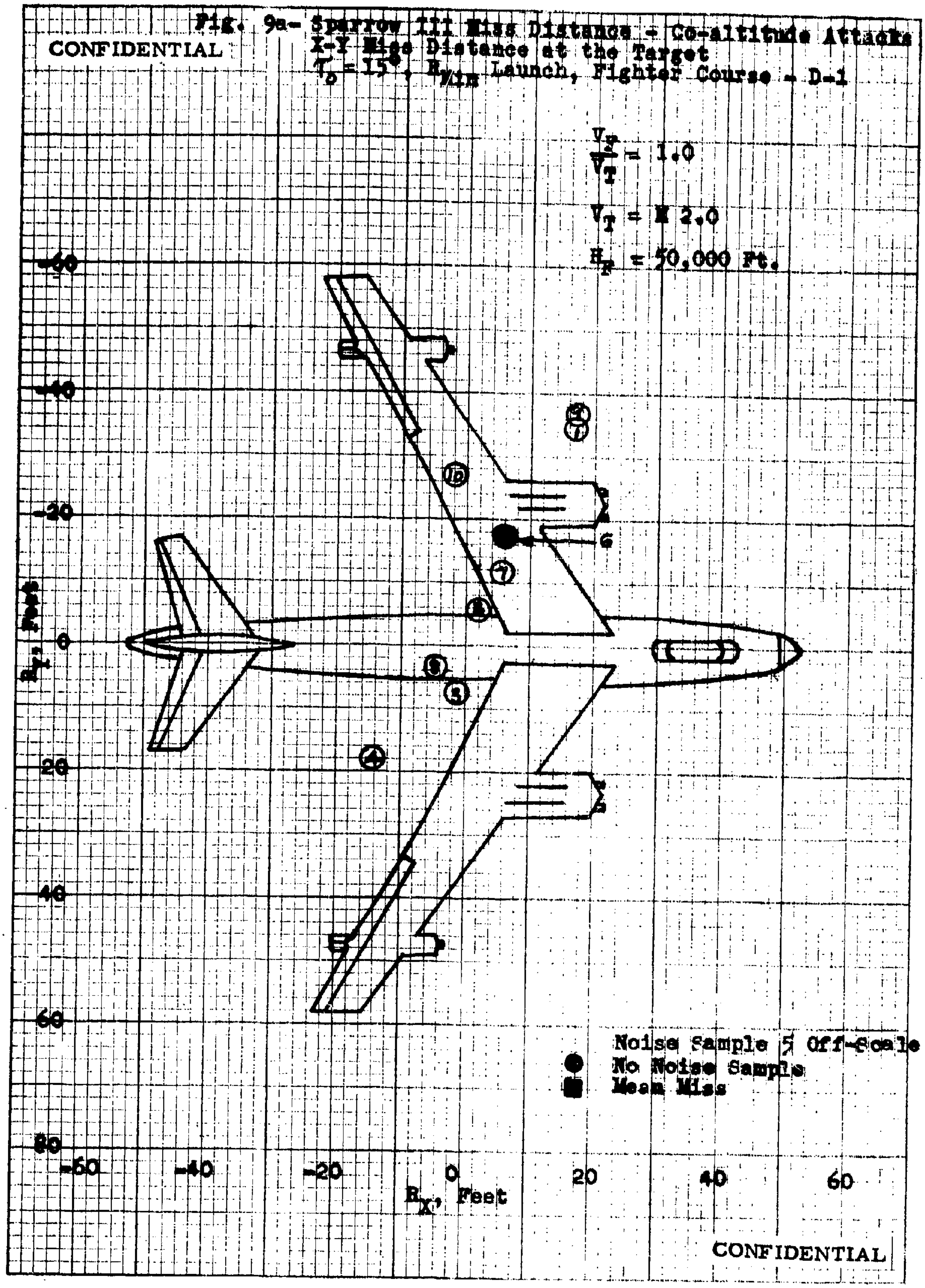

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Fig. 9b- Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
$\tau_o = 15^\circ$, R_{Min} Launch, Fighter Course - D-1

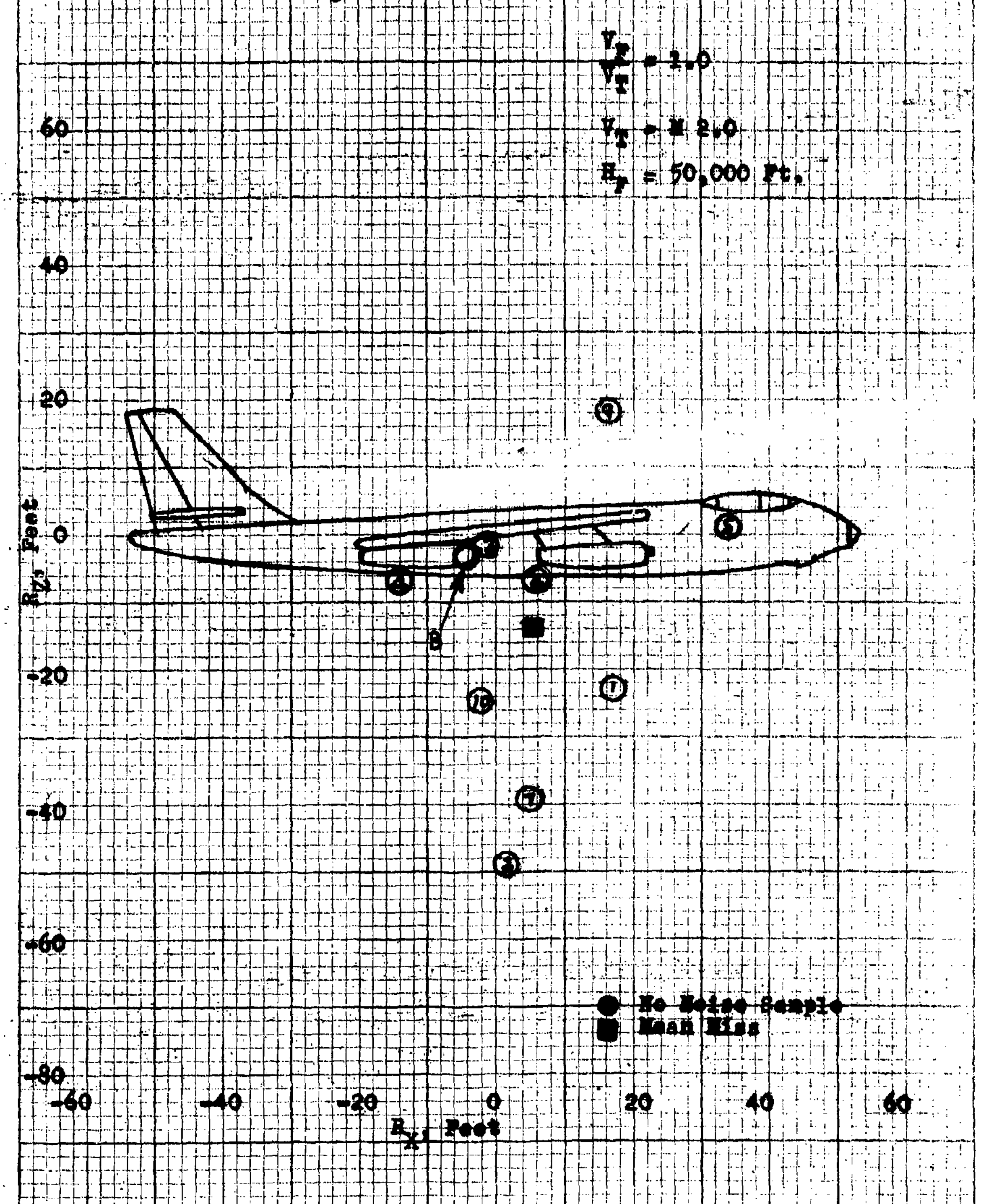

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Fig. 9c - Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
$\tau_o = 15^\circ$, R_{Min} Launch, Fighter Course - D-1

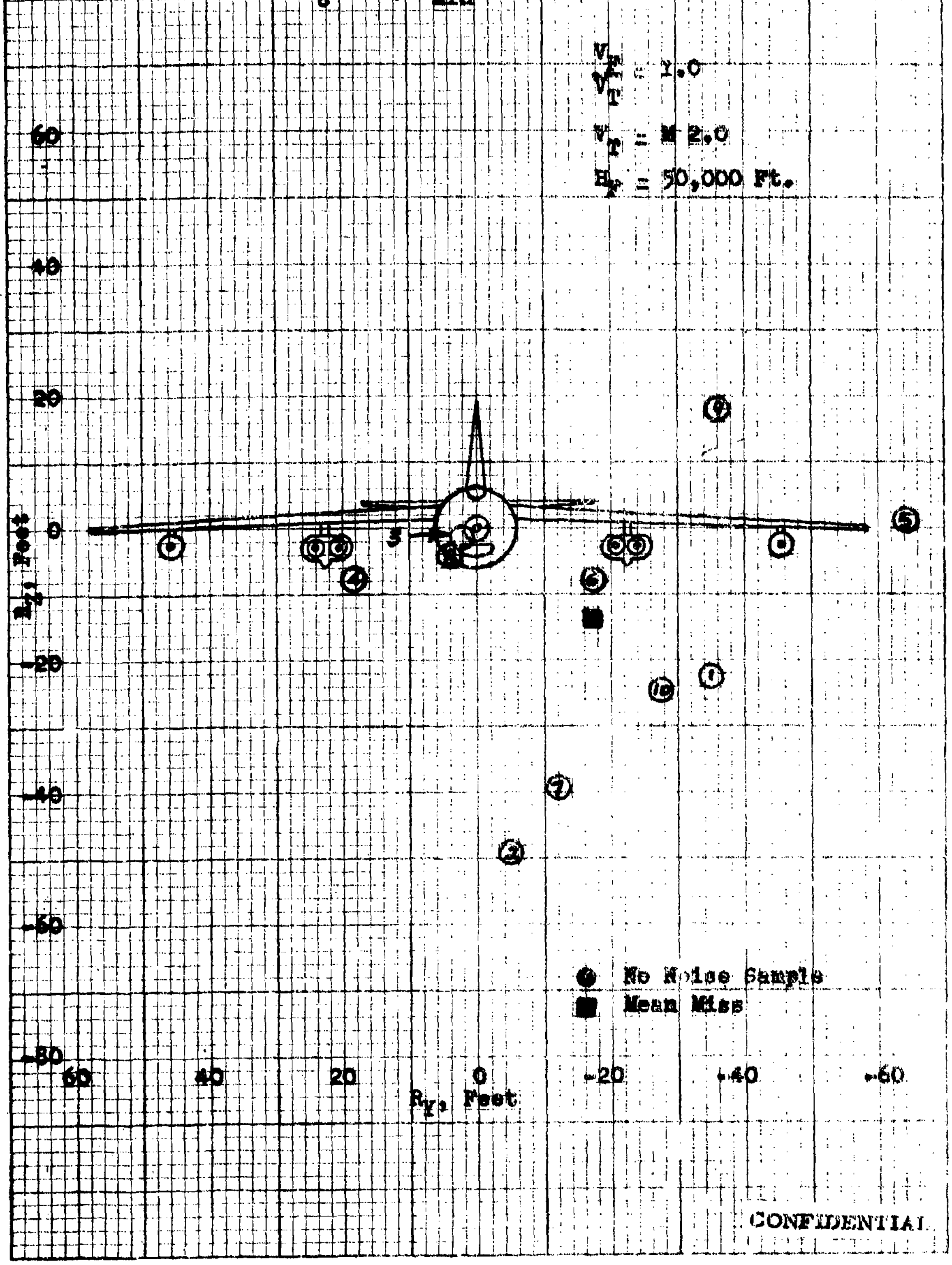

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Fig. 10a.- Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$\tau_0 = 15°$, R_{Max} Launch, Fighter Course - E-1

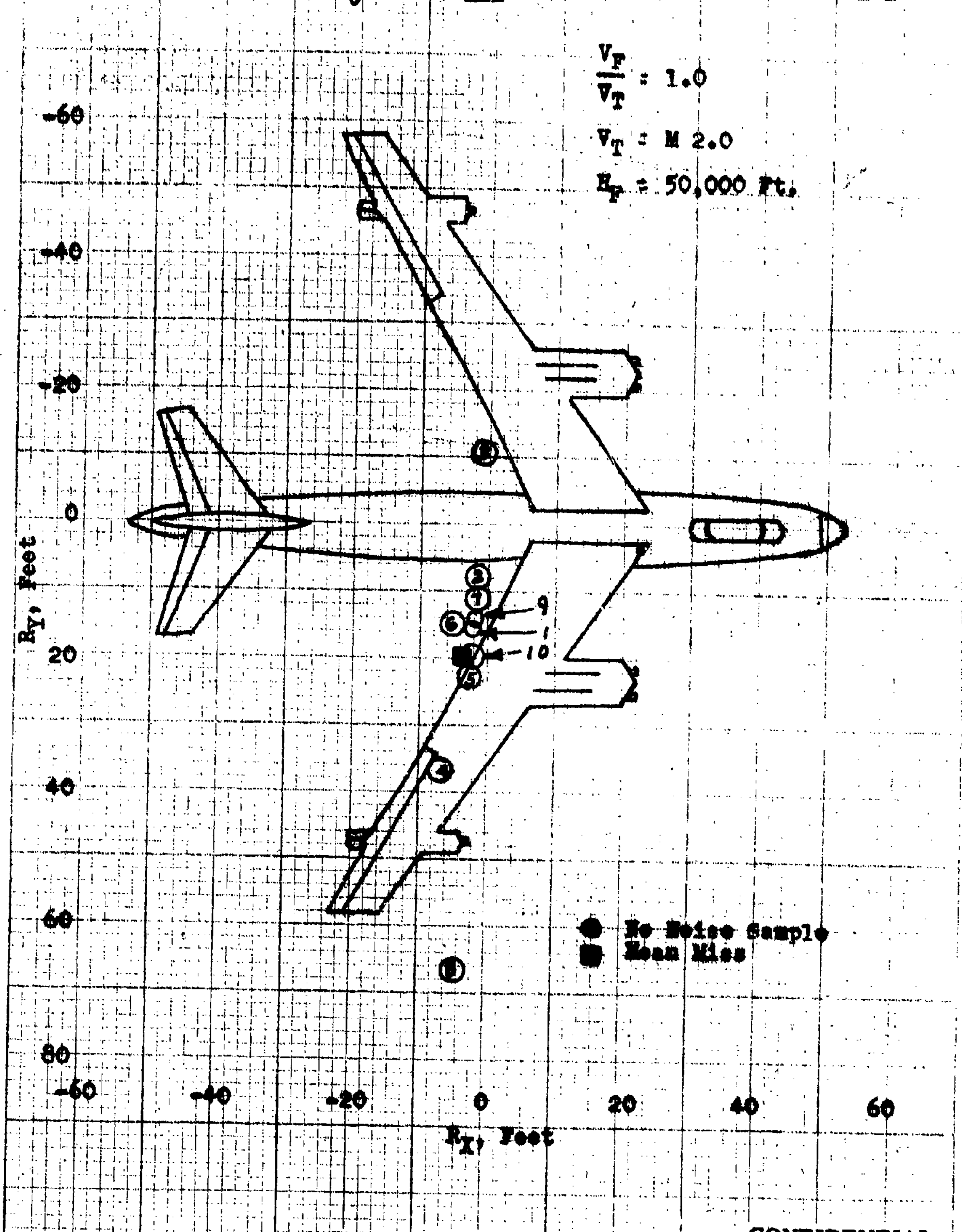

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Fig. 10b - Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
τ_o = 15°, R_{max} Launch, Fighter Course - E-1

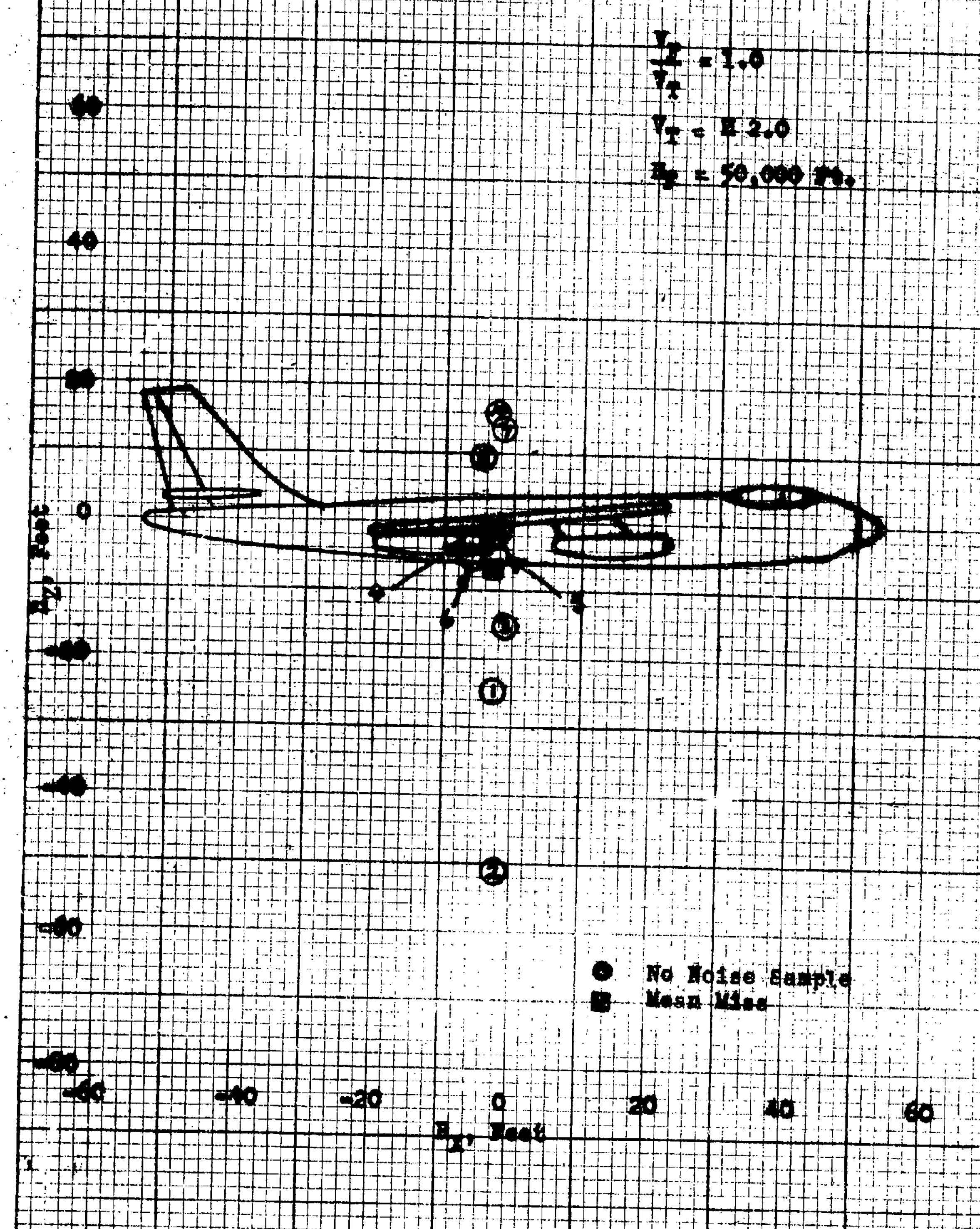

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Fig. 106 - Sparrow III Miss Distance ... Altitude Attacks
Y-Z Miss Distance at the ...
η_o = 15°, R_{Max} Launch, ...

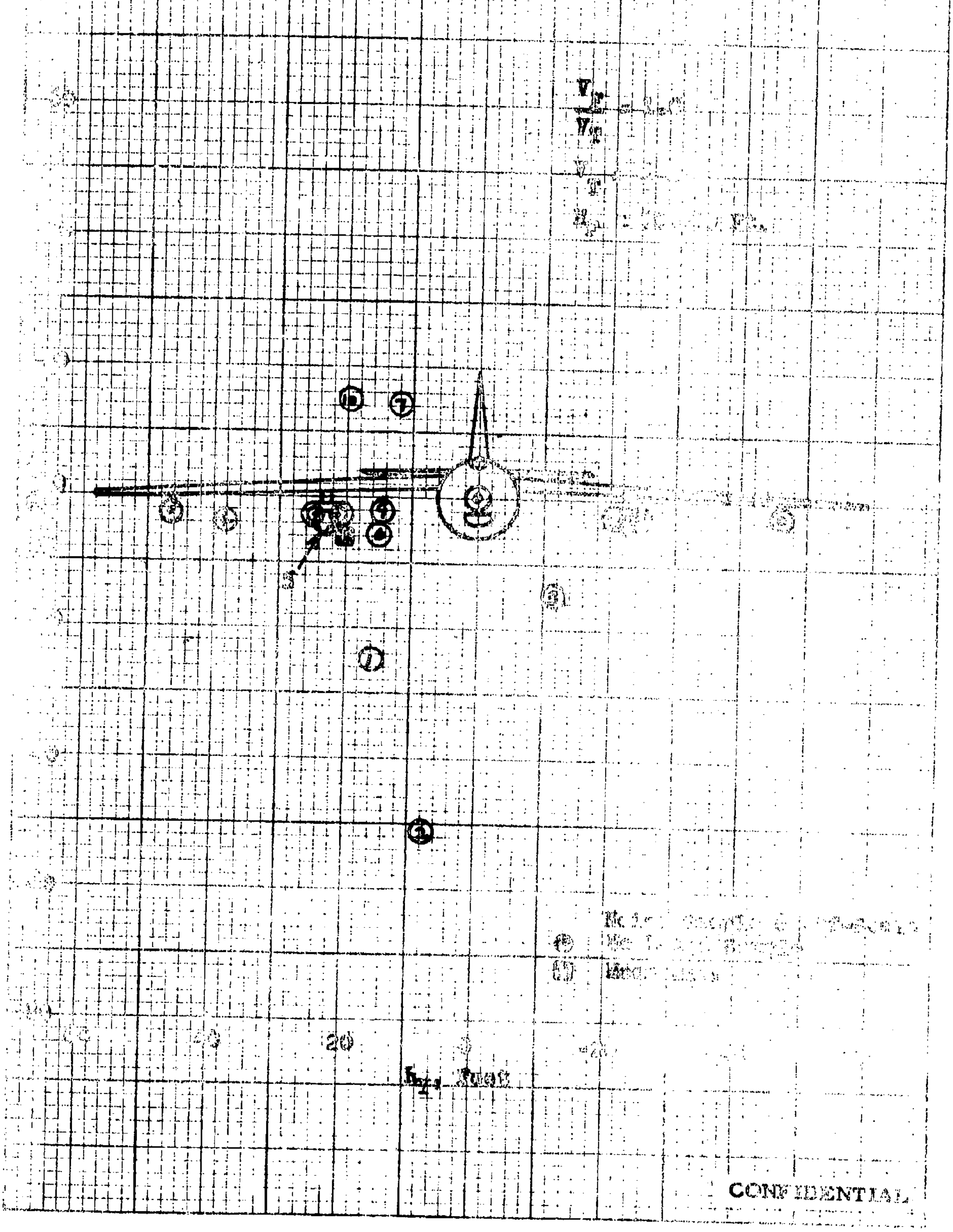

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Fig. 11a - Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$T_o + 15°$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course - E-1

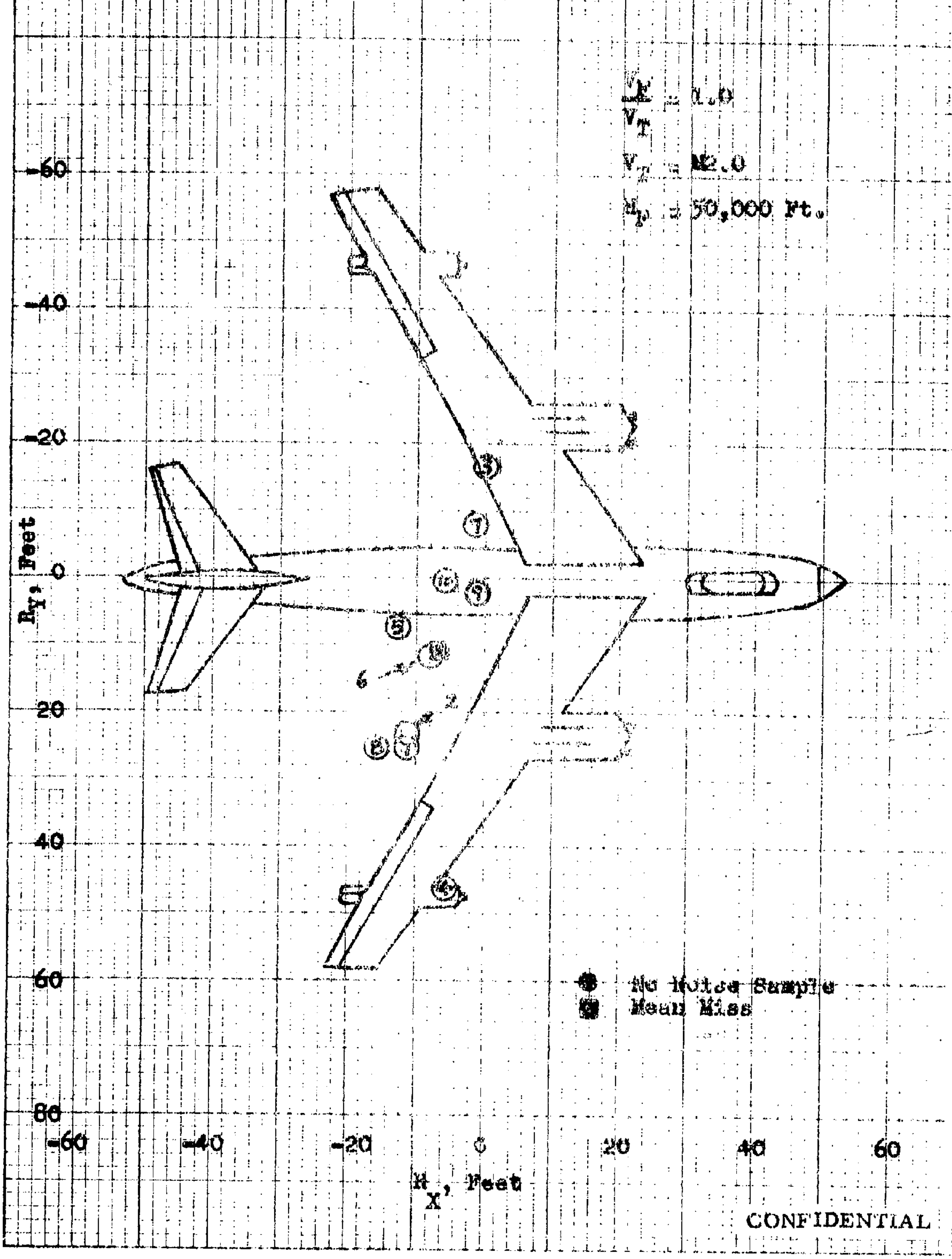

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Fig. 11b-Sparrow III Miss Distance-Co-altitude Attacks
X-Z Miss Distance at the Target
$\tau_o = 15^\circ$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course - E-1

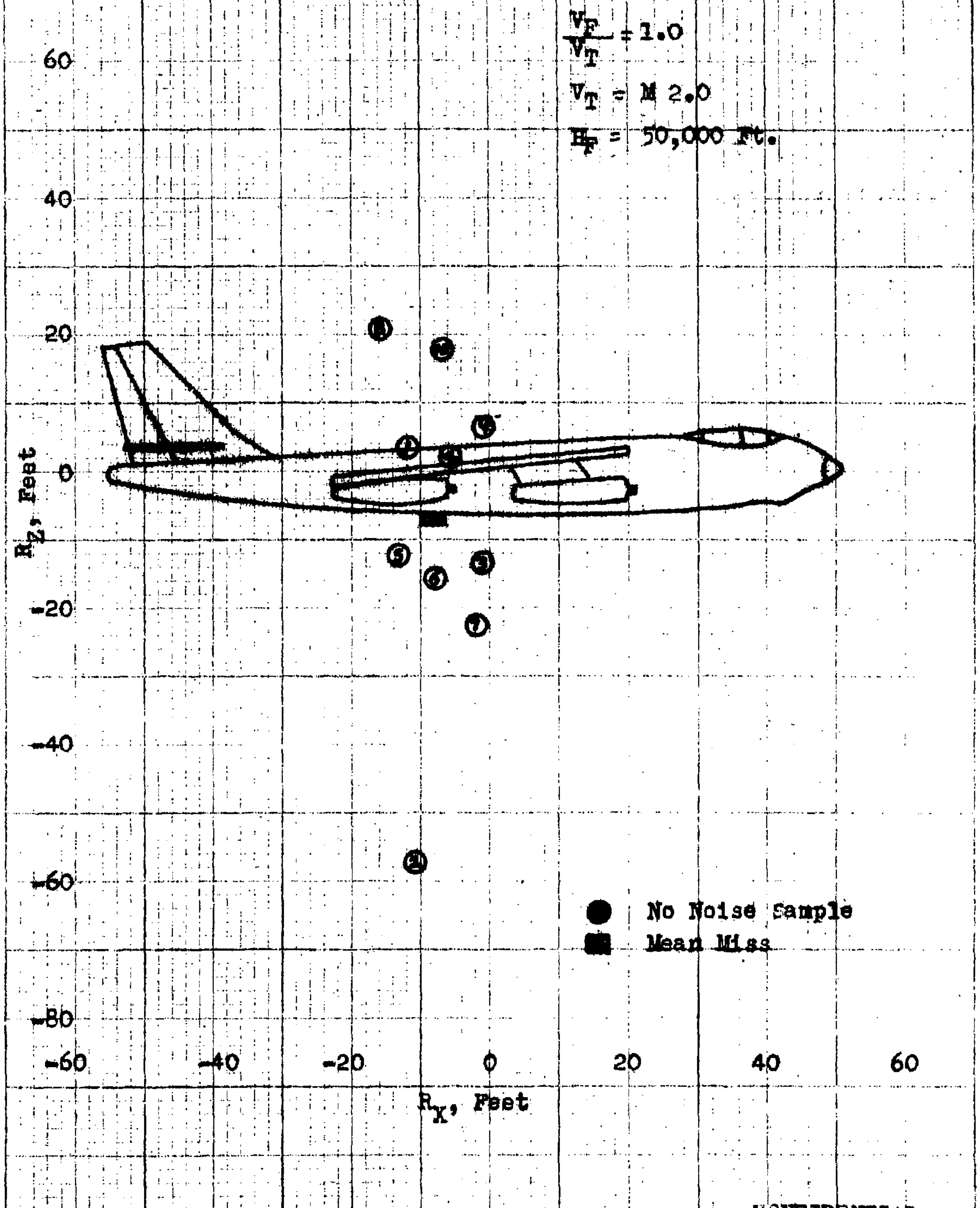

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Fig. Tc- Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
$\lambda_o = 15^o$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch,
Fighter Course - E-1

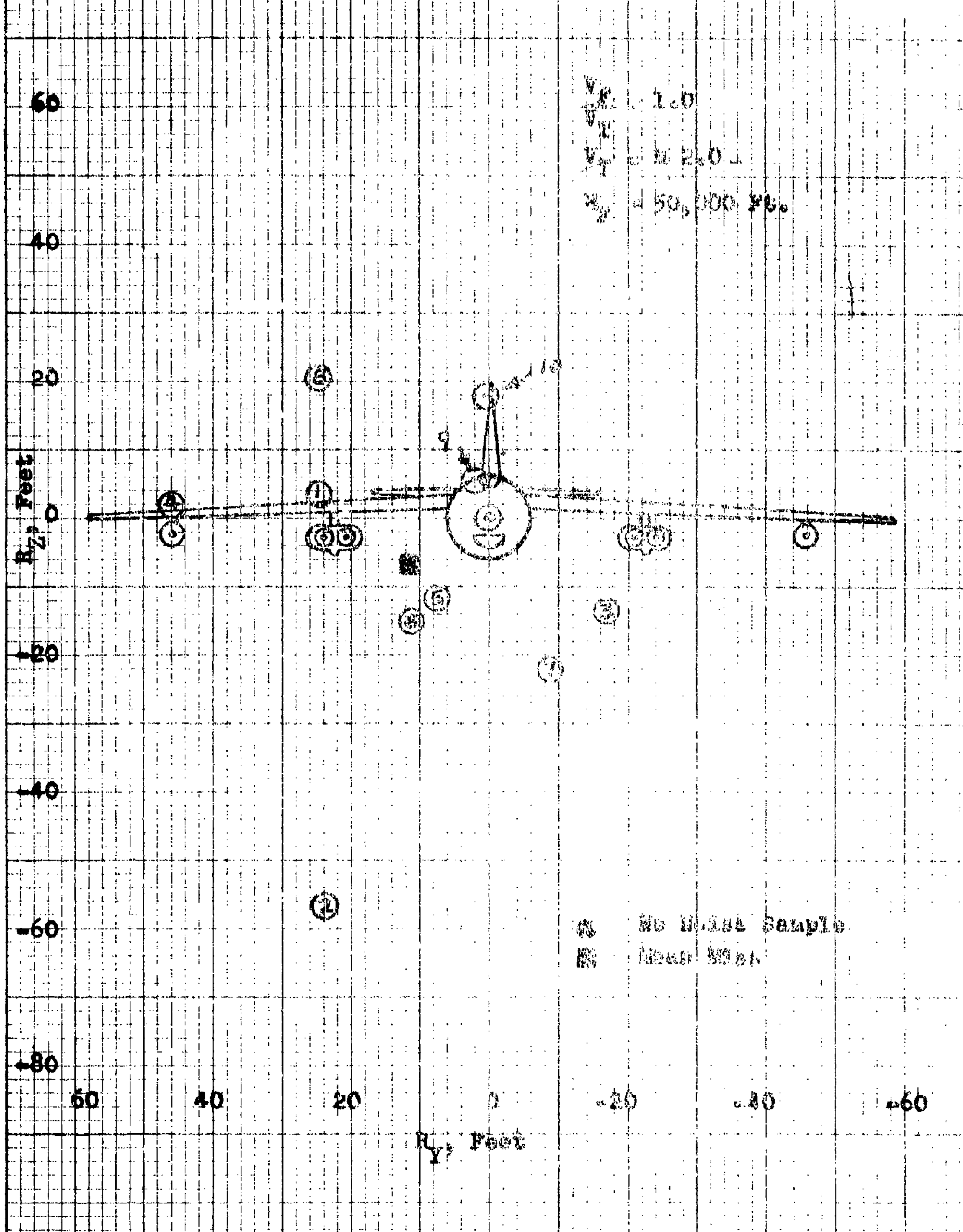

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Fig. 12a- Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$\psi_0 = 15^\circ$, R_{Min} Launch, Fighter Course - E-1

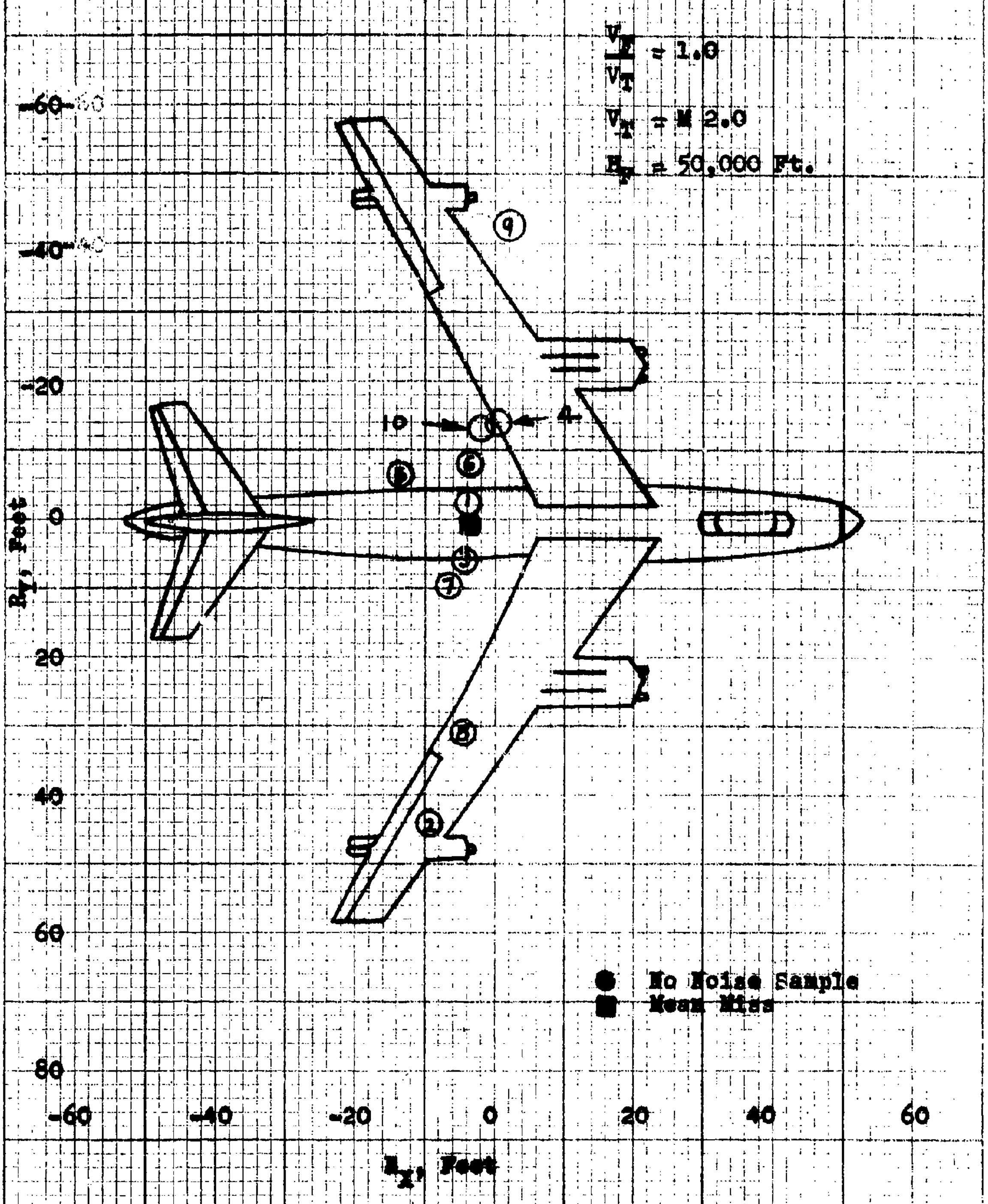

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Fig. 12b- Sparrow III Miss Distance- Co-altitude Attacks
X-Z Miss Distance at the Target
$\sigma_o = 15^{\circ}$, R_{Min} Launch, Fighter Course - E-1

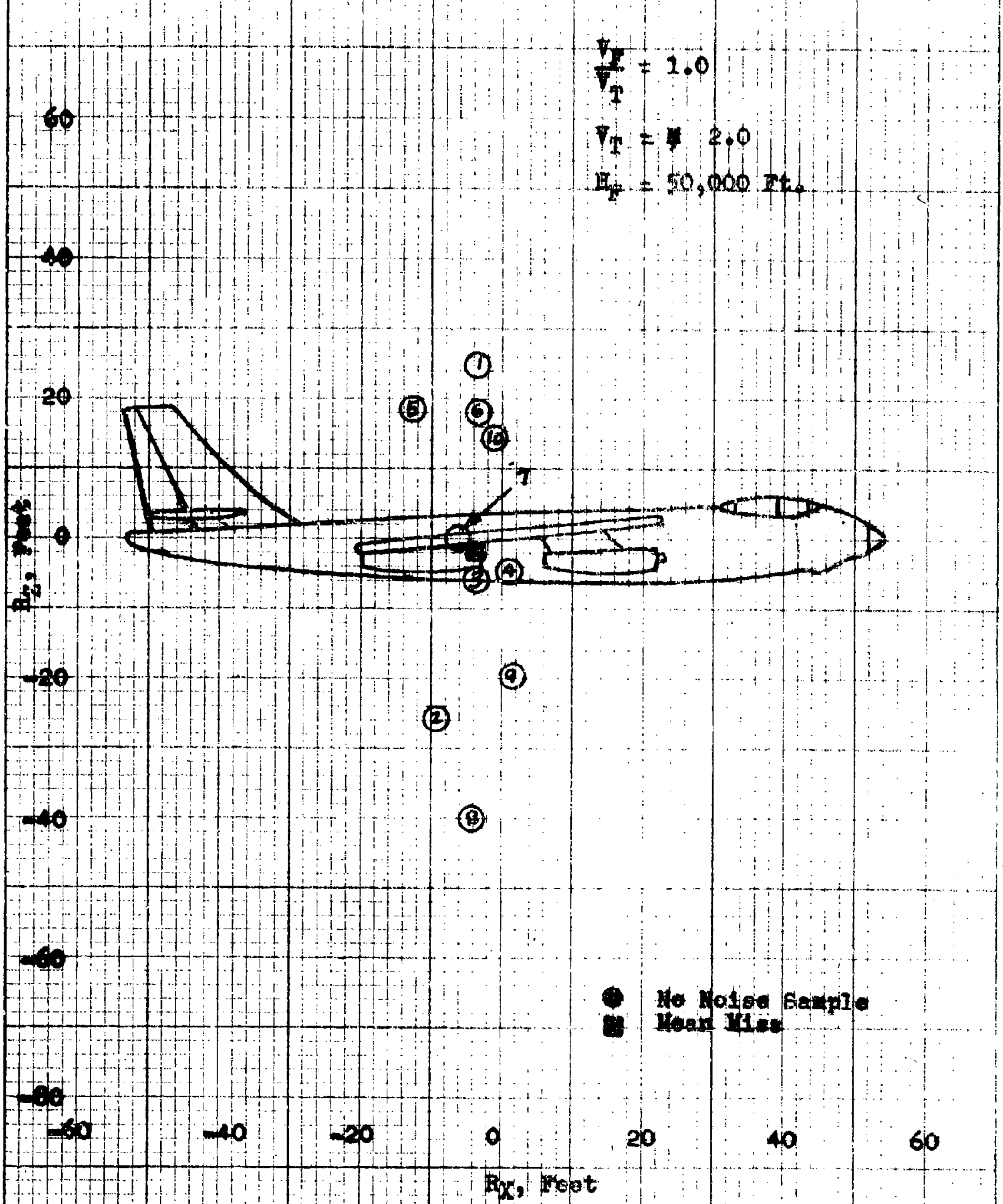

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Fig. 12c- Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
τ_o = 15°, R_{Min} Launch, Fighter Course - E-1

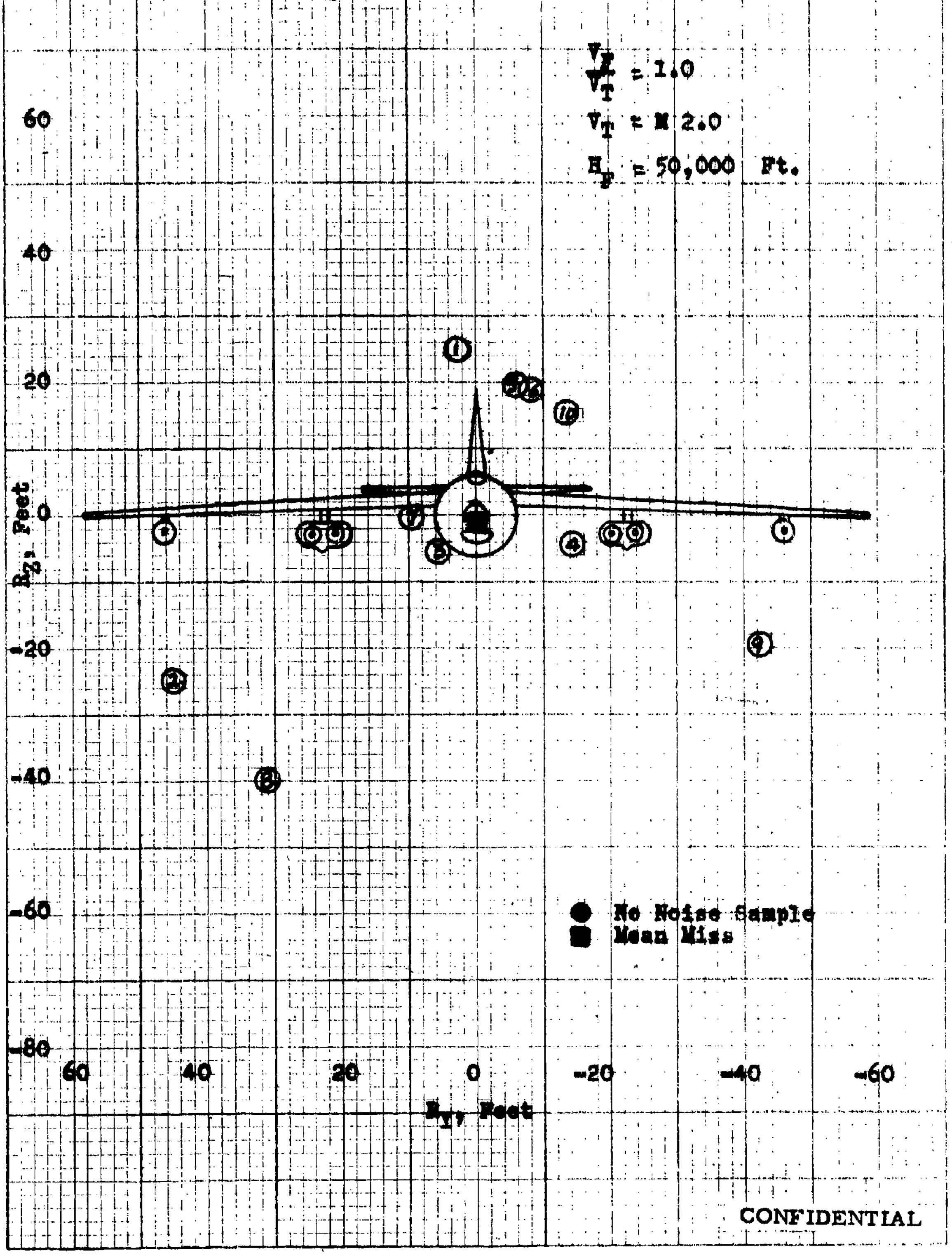

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Fig. 13a- Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$\Upsilon_o = 15^o$, R_{Max} Launch, Fighter Course - G-3

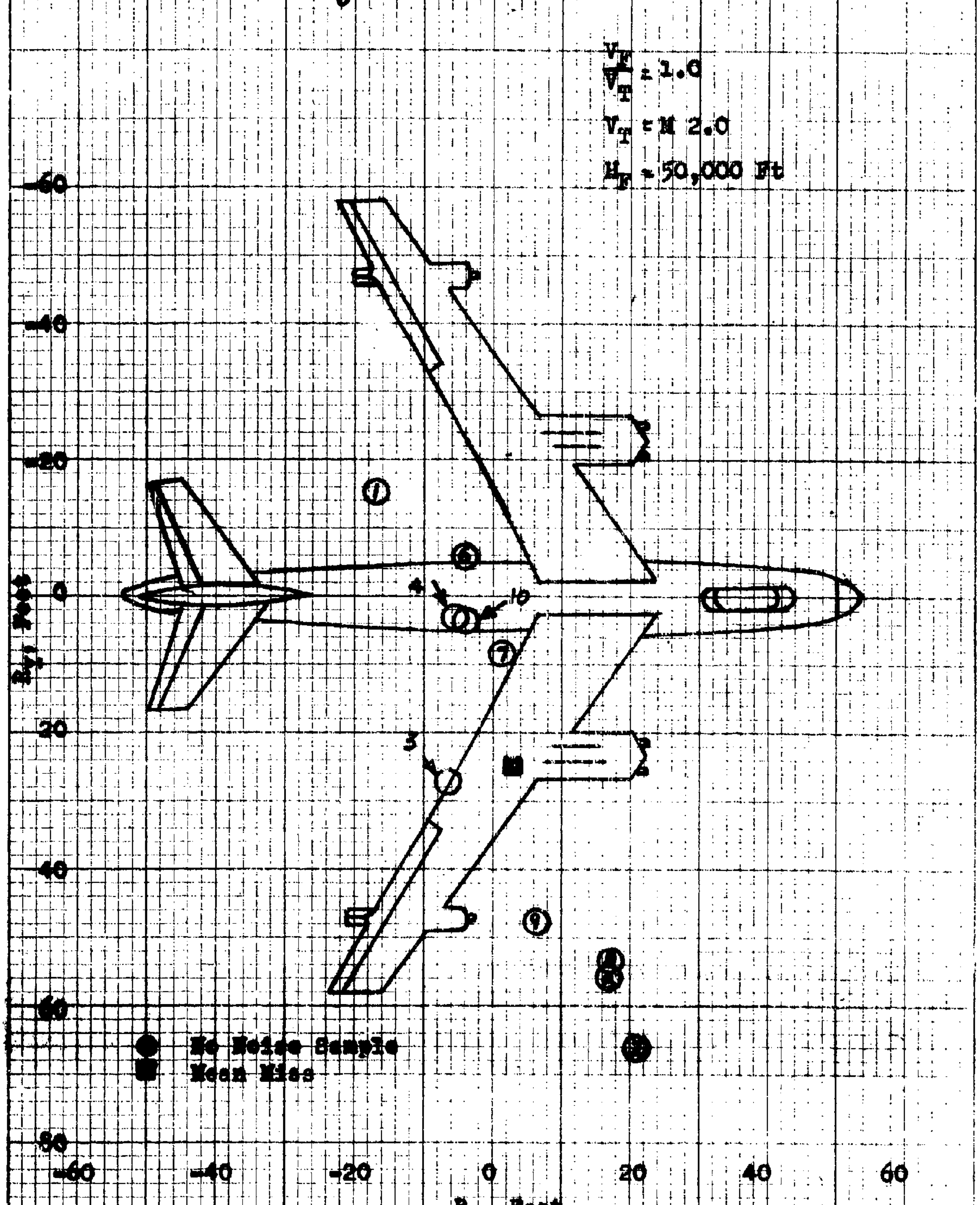

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Fig.13b- Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
$\tau_0 = 15°$, R_{Max} Launch, Fighter Course - G-3

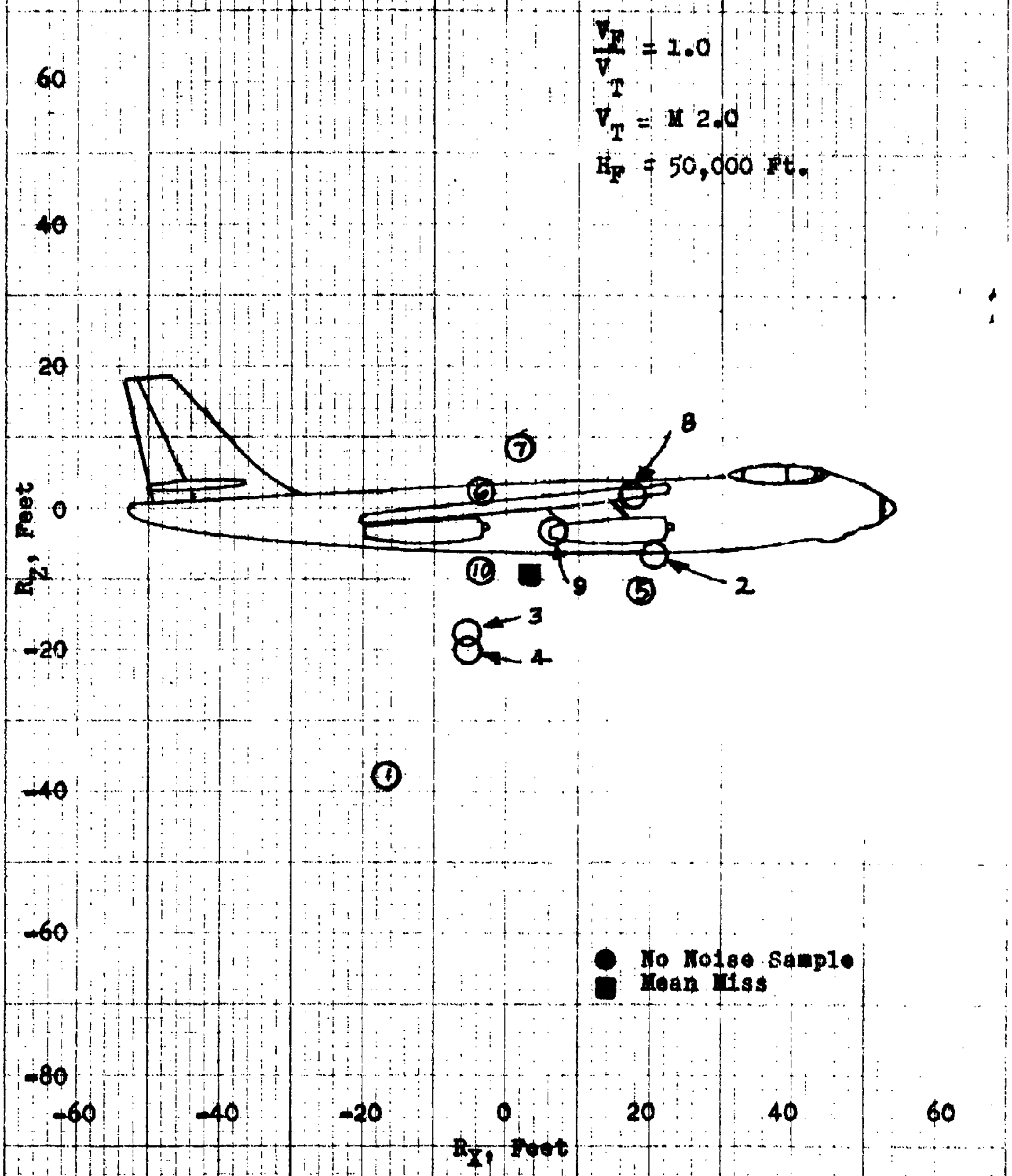

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Fig. 13b- Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
$\psi_o = 15^\circ$, R_{Max} Launch, Fighter Course - G-3

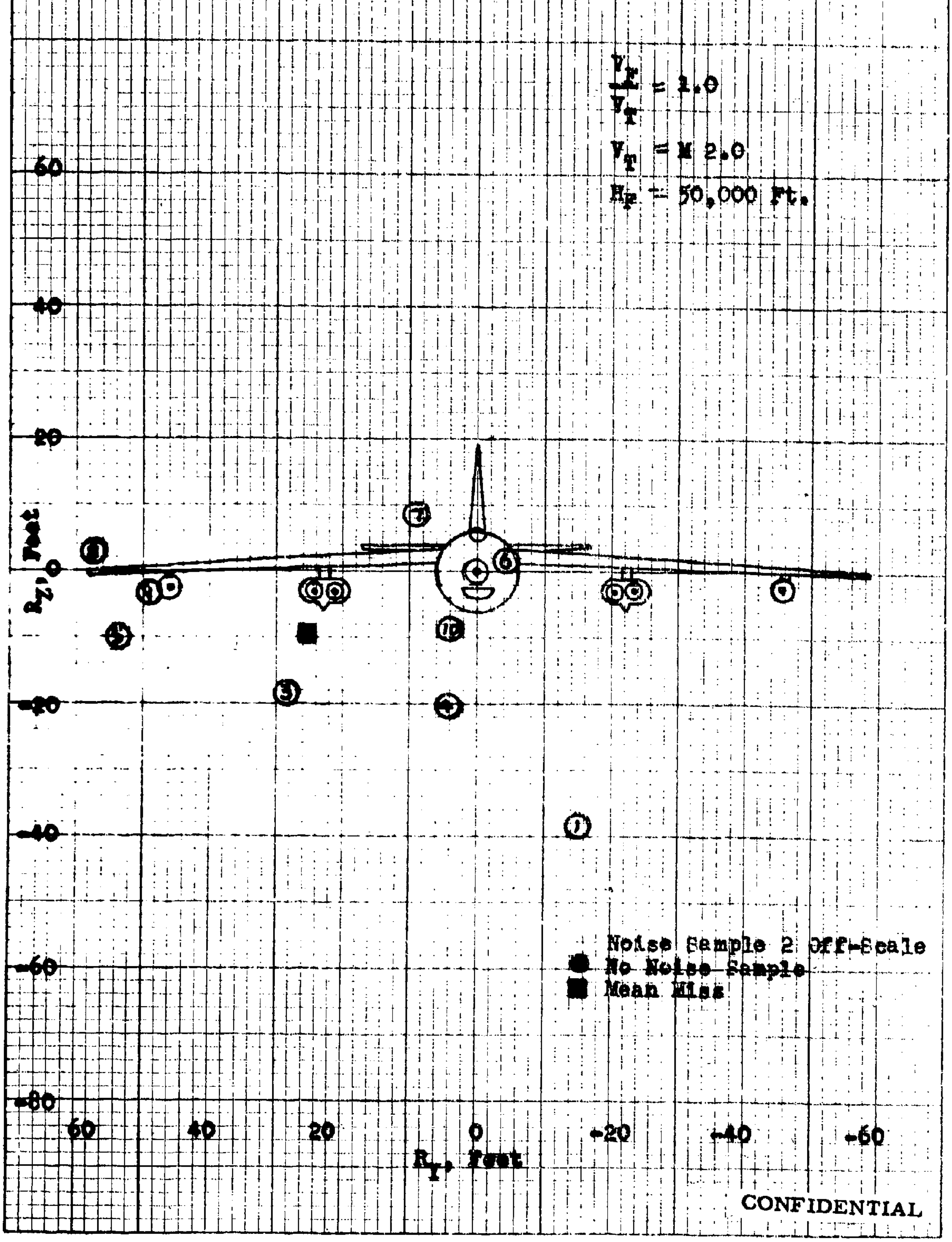

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Fig. 14a – Sparrow III Miss Distance – Co-altitude Attacks
X-Y Miss Distance at the Target
$\tau_o = 15^o$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course – C-3

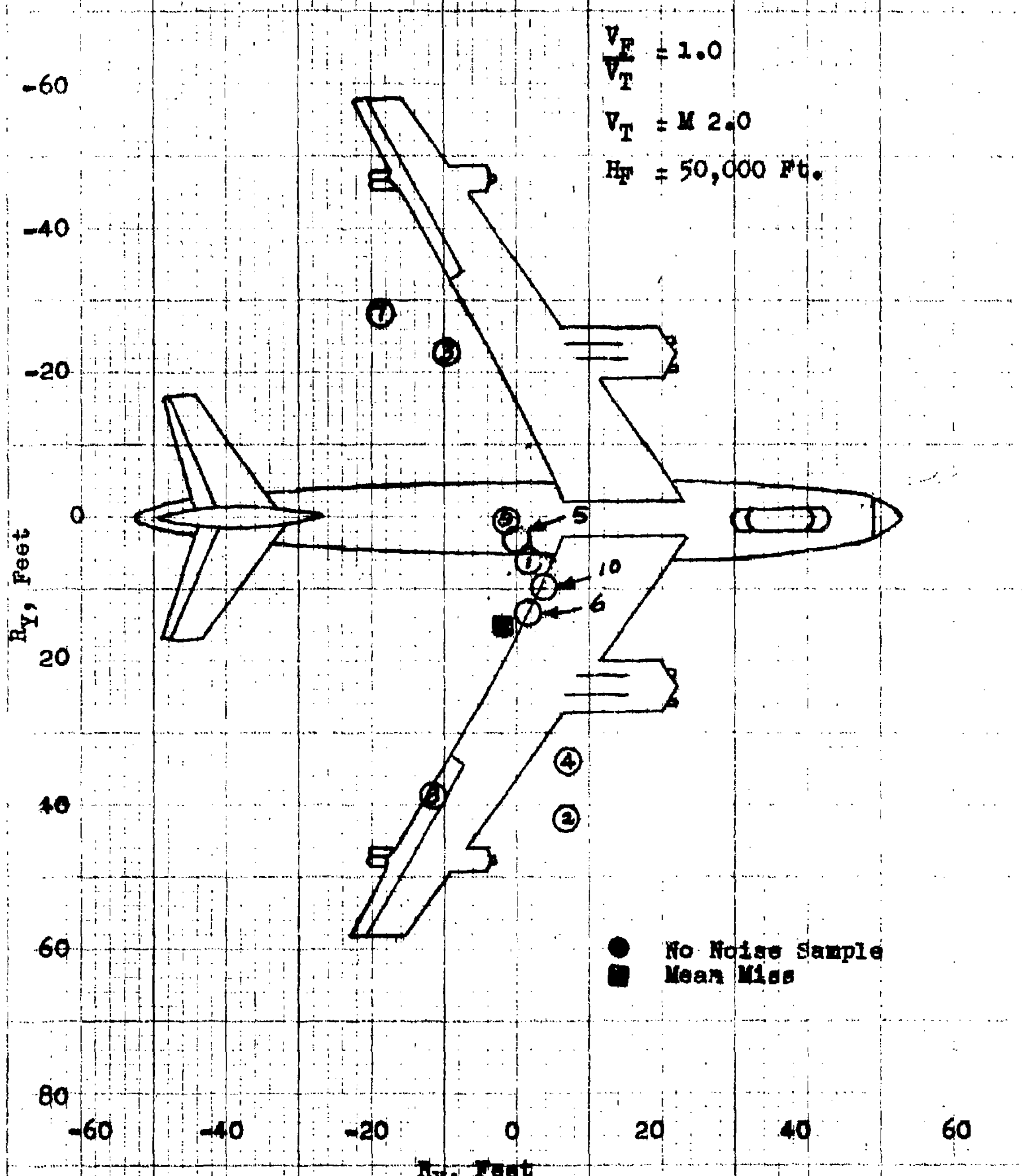

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Fig. 14b Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
$\tau_s = 15°$, $\frac{1}{2}(R_{max} + R_{min})$ Launch
Fighter Course - C-3

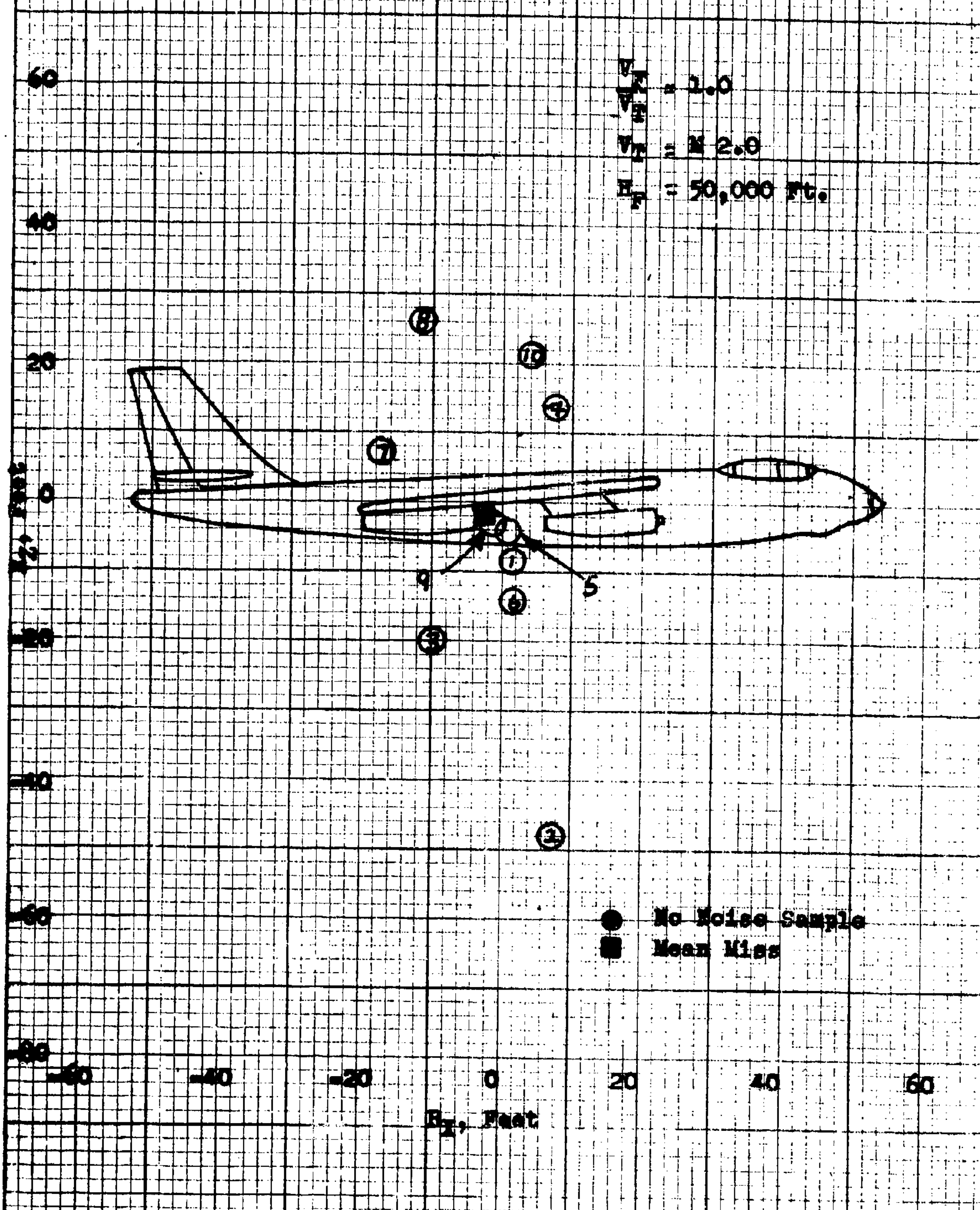

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Fig. 14e - Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
$\Upsilon_o = 15°$, $\frac{1}{2}(R_{max} + R_{min})$ Launch
Fighter Course - G-3

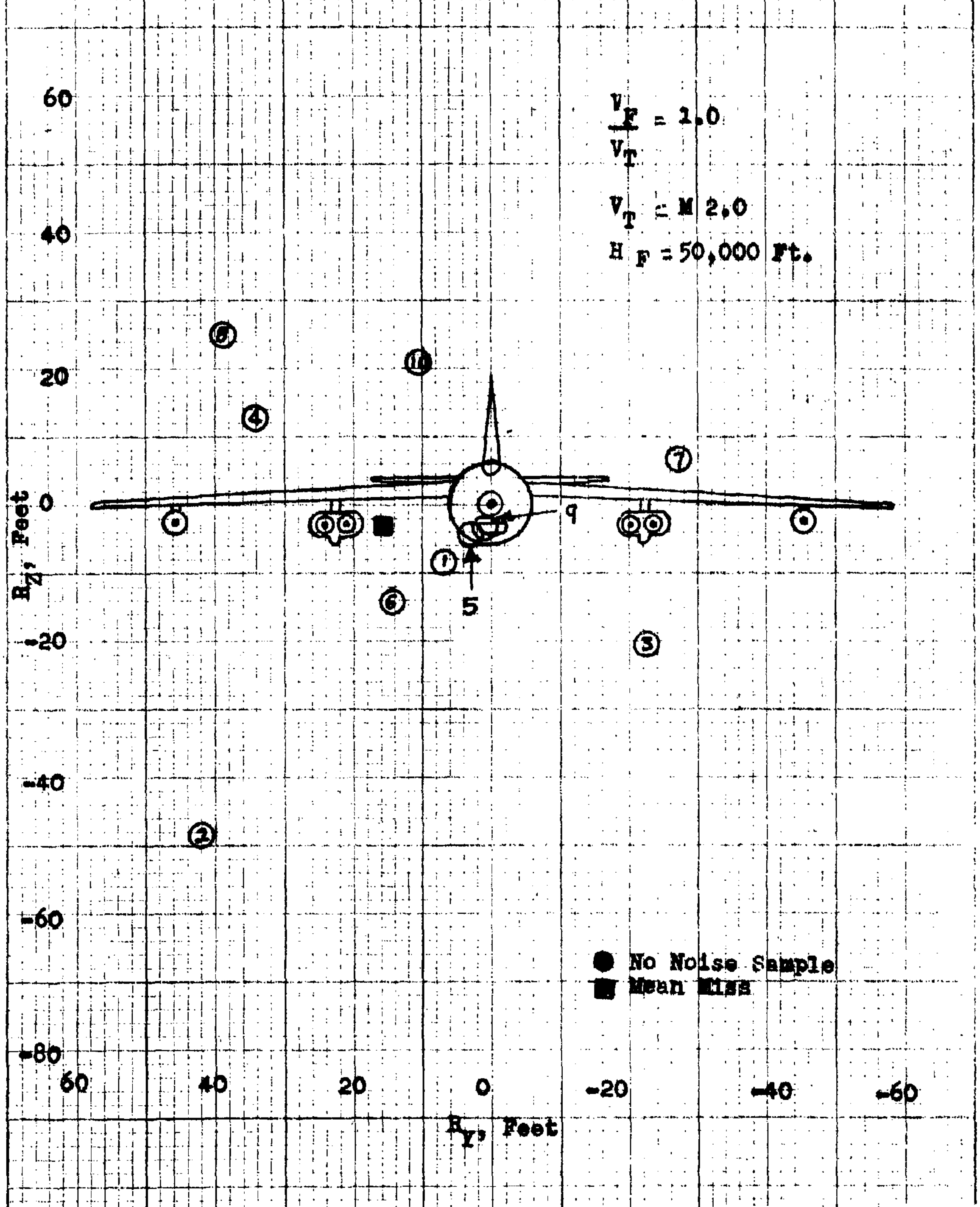

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Fig. 15a- Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
T_b - 15°, R_{Min} Launch, Fighter Course - G-3

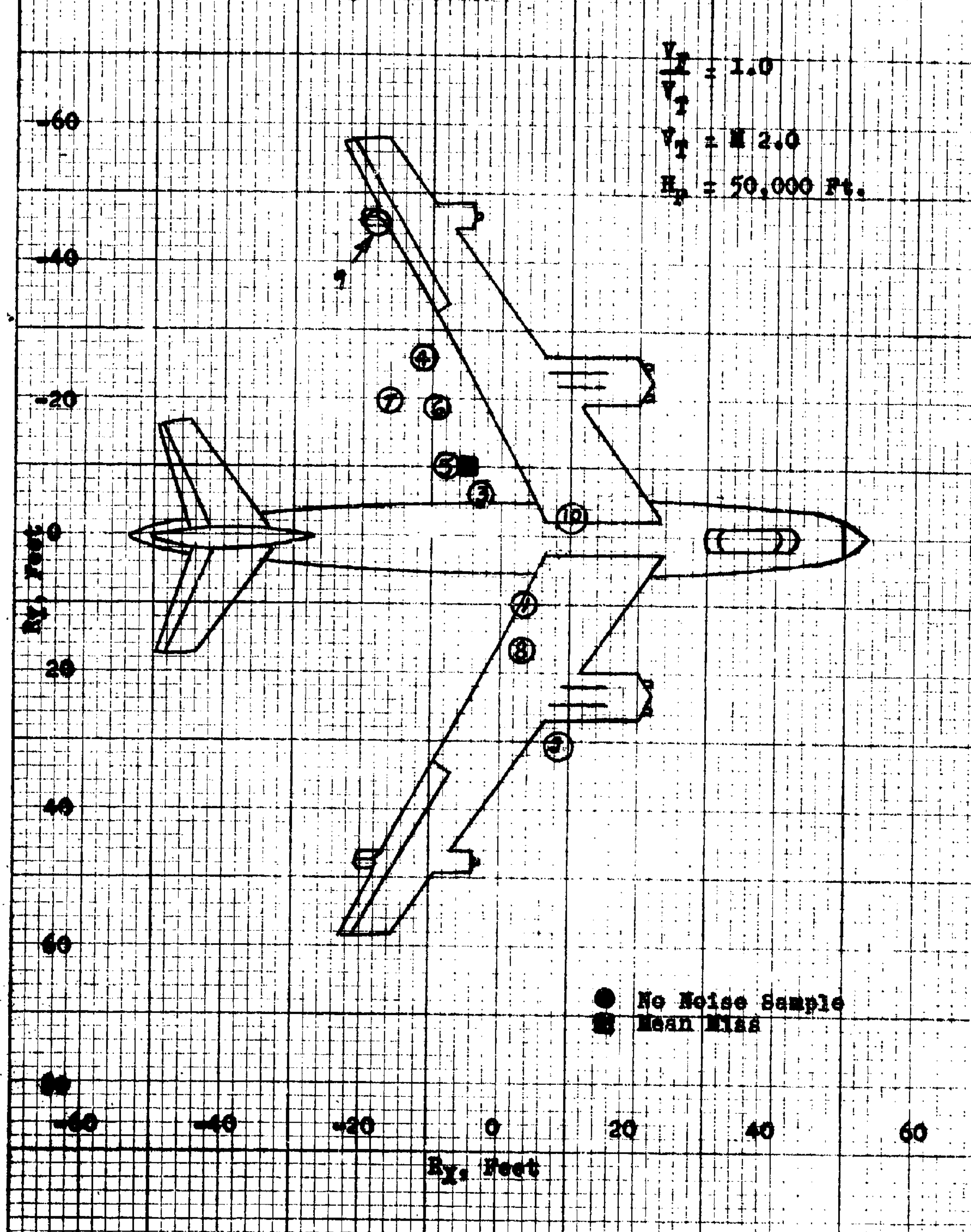

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Fig. 15b - Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
$\tau_p = 15°$, R_{Min} Launch, Fighter Course - G-3

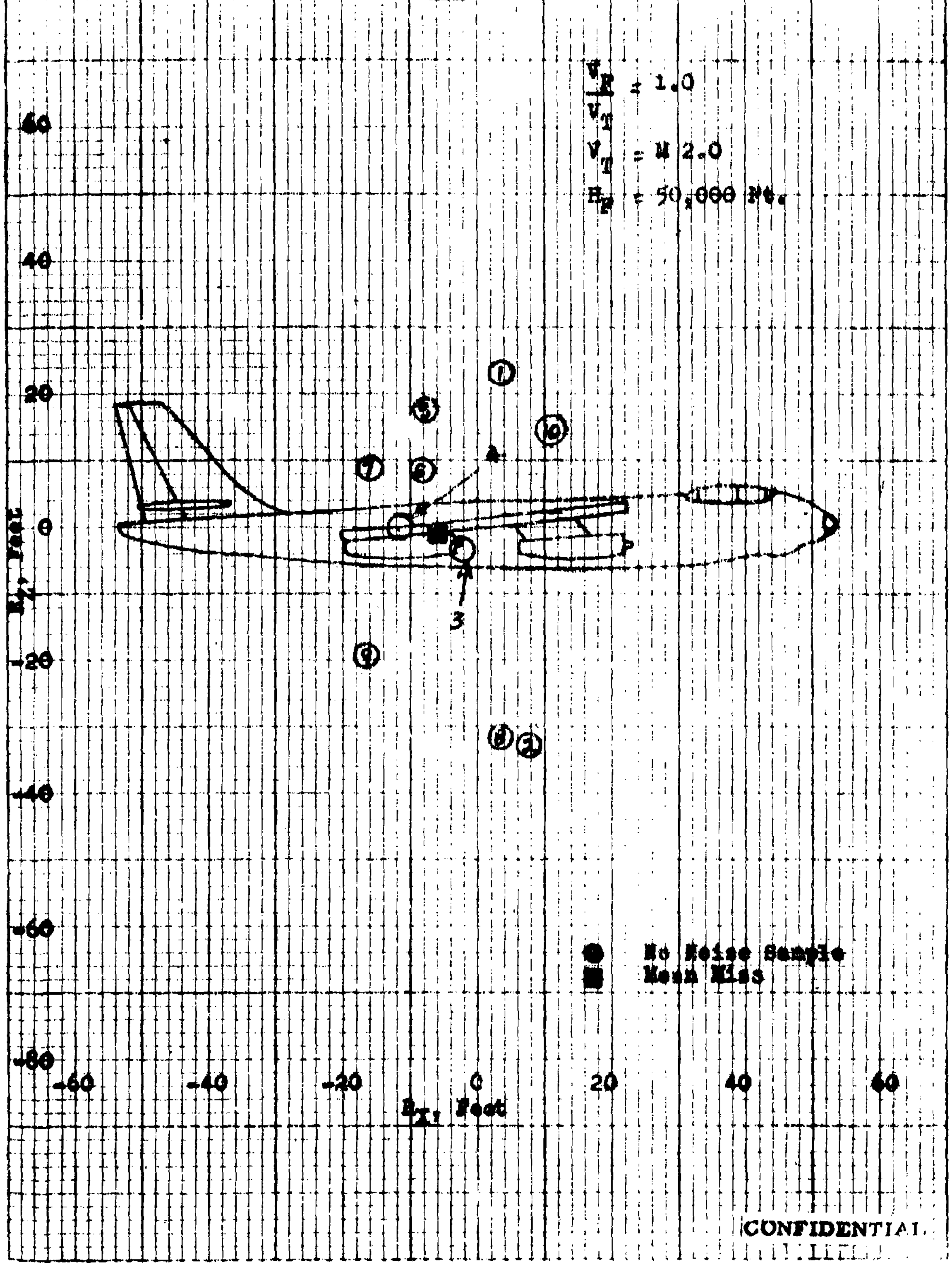

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Fig.15c- Sparrow III Miss Distance - Co-altitude Attacks
Y-Z Miss Distance at the Target
$\tau_o = 15^\circ$, R_{Min} Launch, Fighter Course - G-3

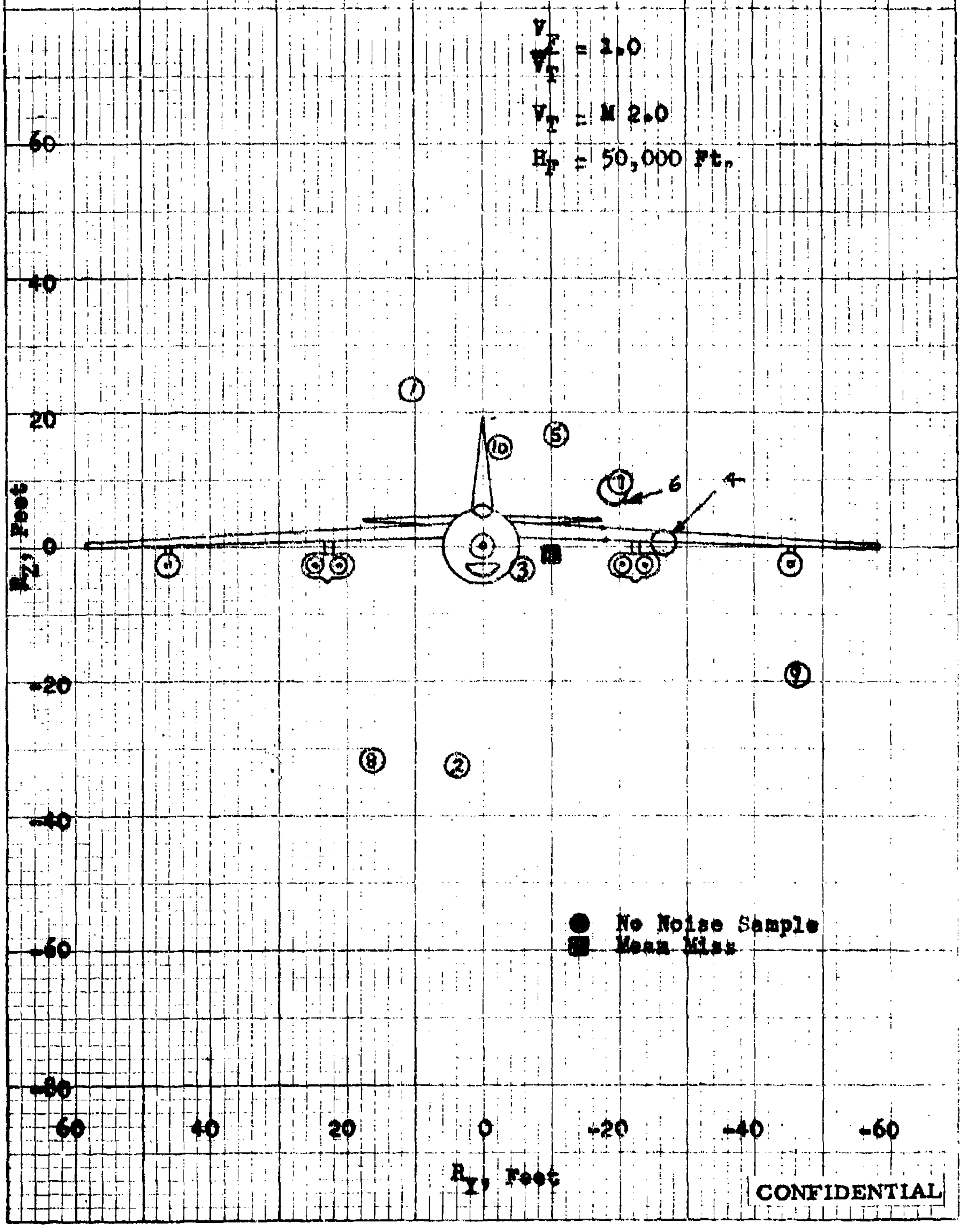

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Fig. 16a - Sparrow III Miss Distance-Co-Altitude Attacks
X-Y Miss Distance at the Target
γ_0 = 60°, R_{max} Launch, Fighter Course - D-1

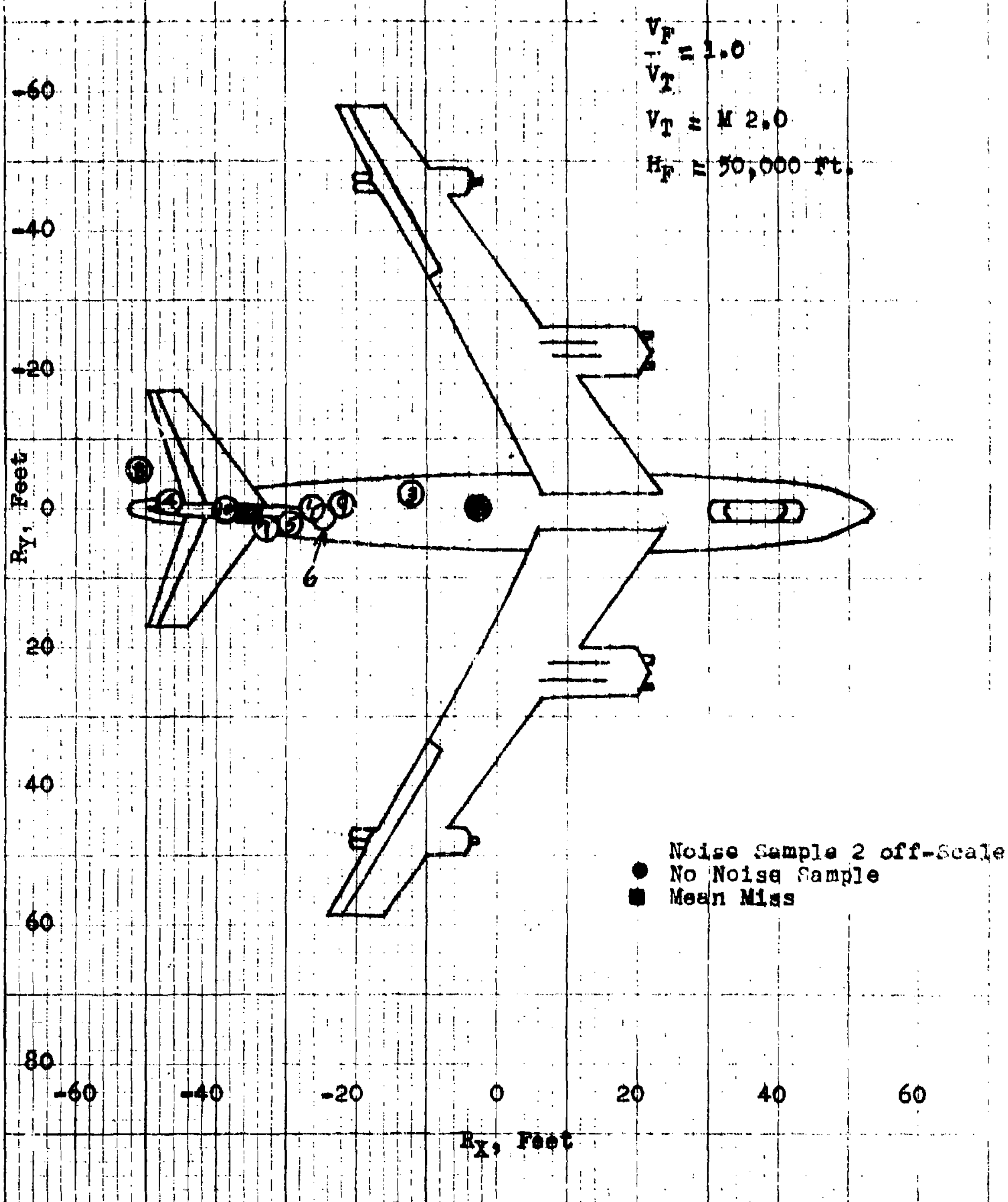

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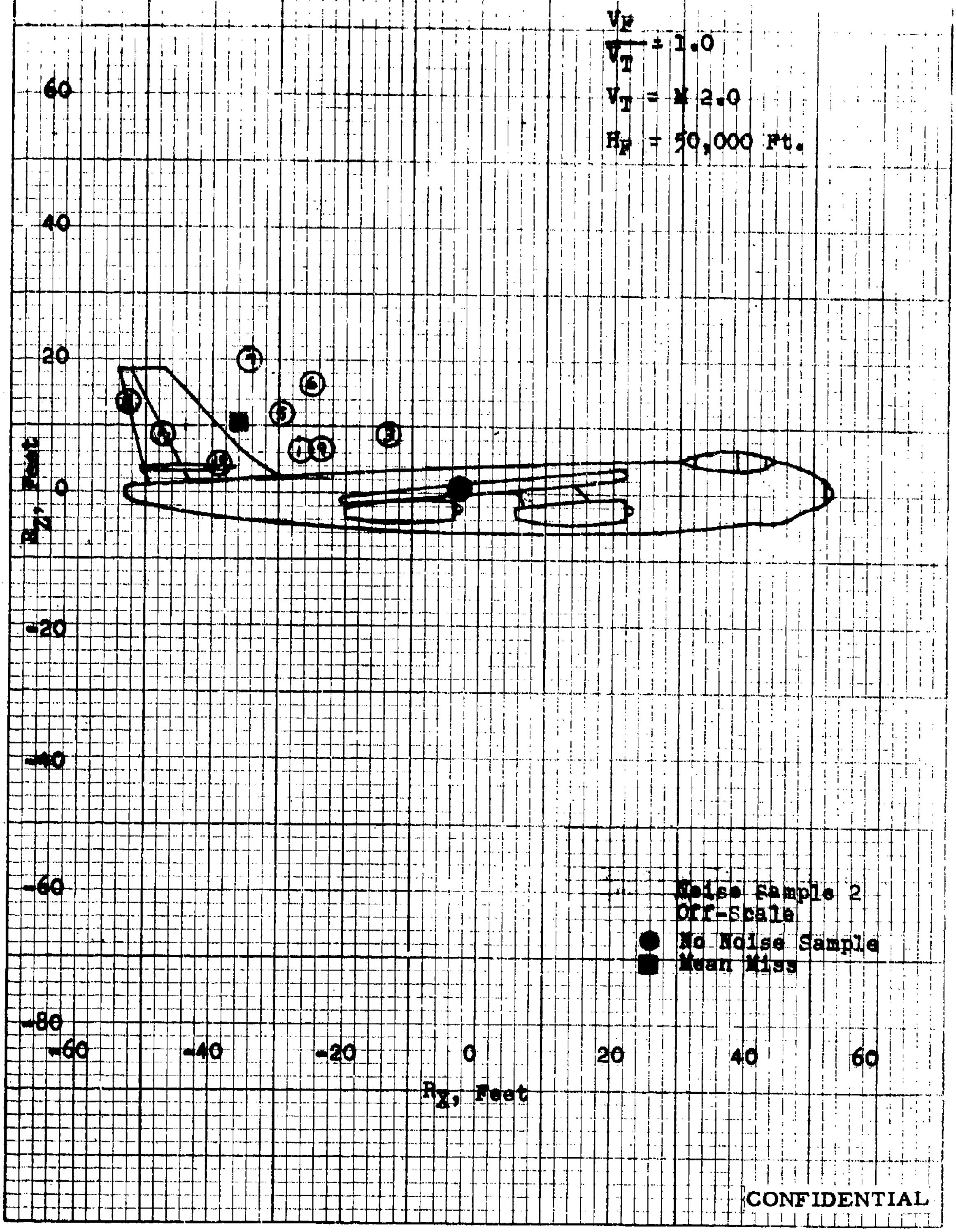
Fig. 16-8 Sparrow III Miss Distance - Co-altitude Attacks
X-Z Miss Distance at the Target
$\Gamma_o = 60°$, R_{Max} Launch, Fighter Course - D-1



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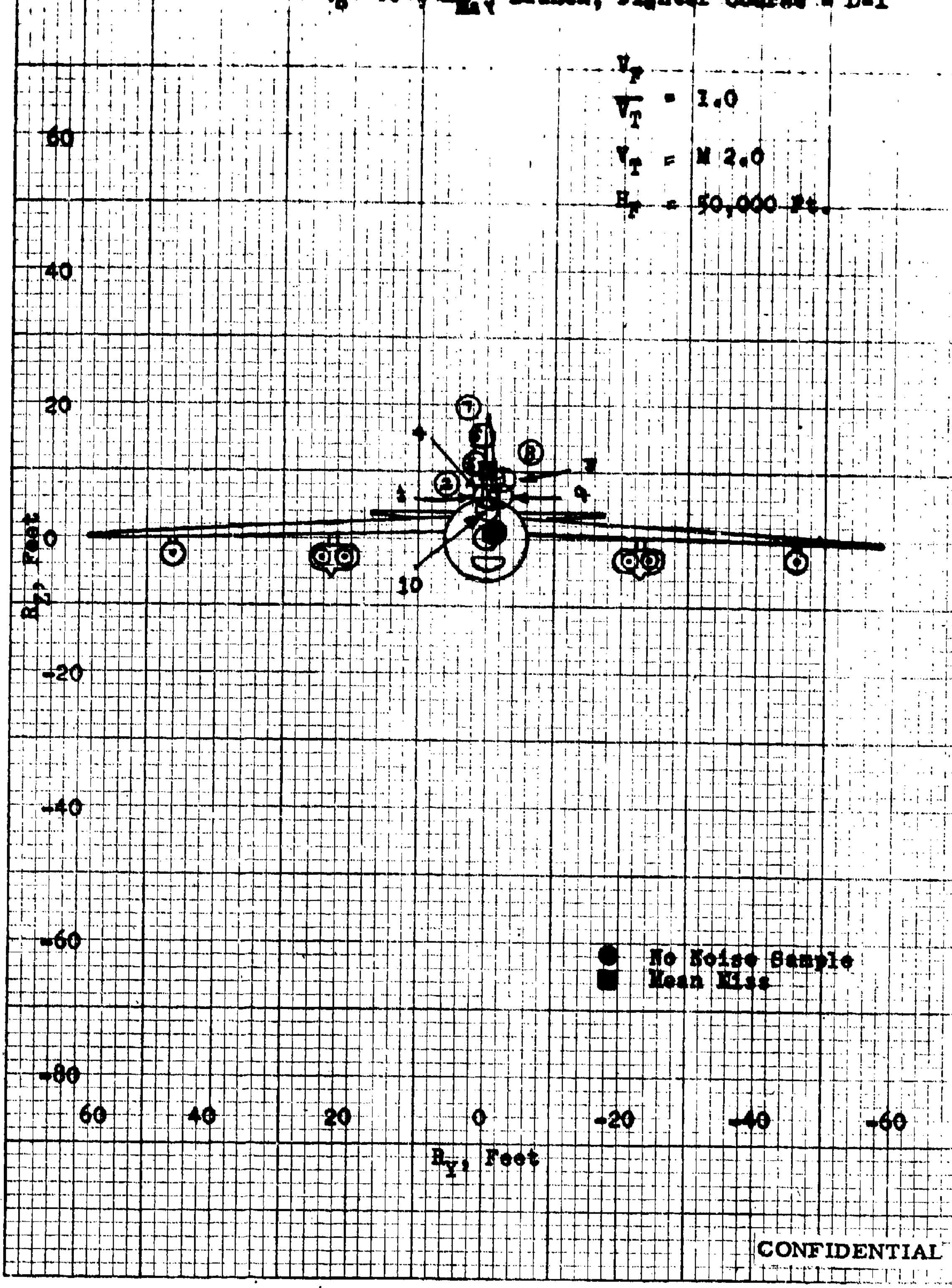

Fig. 16e–Sparrow III Miss Distance – Co-altitude Attacks
Y-Z Miss Distance at the Target
γ_0 = 60°, R_{Max} Launch, Fighter Course – D-1

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Fig.17a - Sparrow III Miss Distance - Co-altitude Attacks
X-Y Miss Distance at the Target
$\gamma_o = 60°$, Launch (T_f+2) Sec after R_{Max}
Fighter Course - D-1

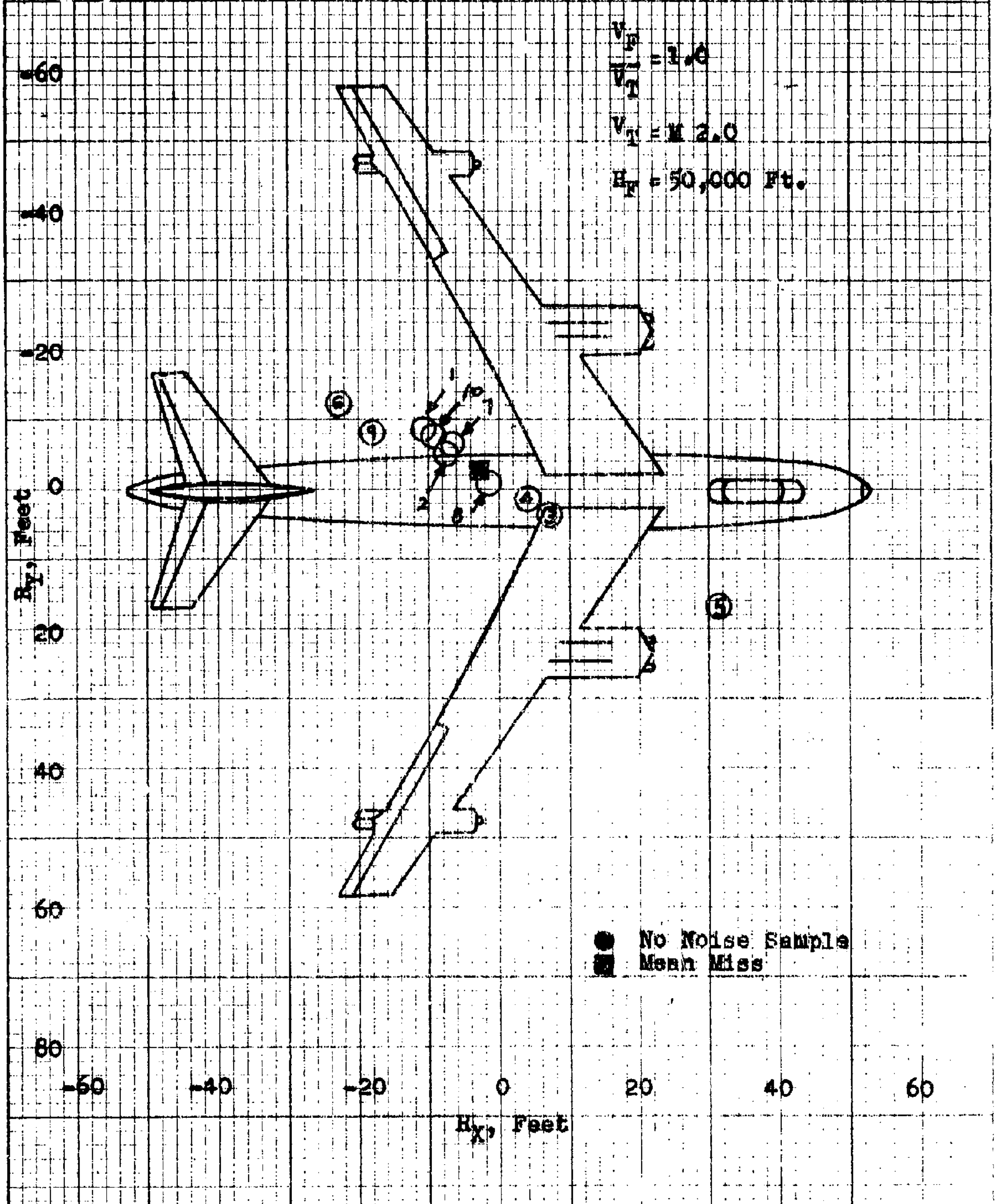

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Fig. 17 Sparrow III Miss Distance – Co-altitude Attacks
X-Z Miss Distance at the Target
$\tau_a = 60^\circ$, Launch ($T_f + 2$) Sec after R_{Max}
Fighter Course – D-1

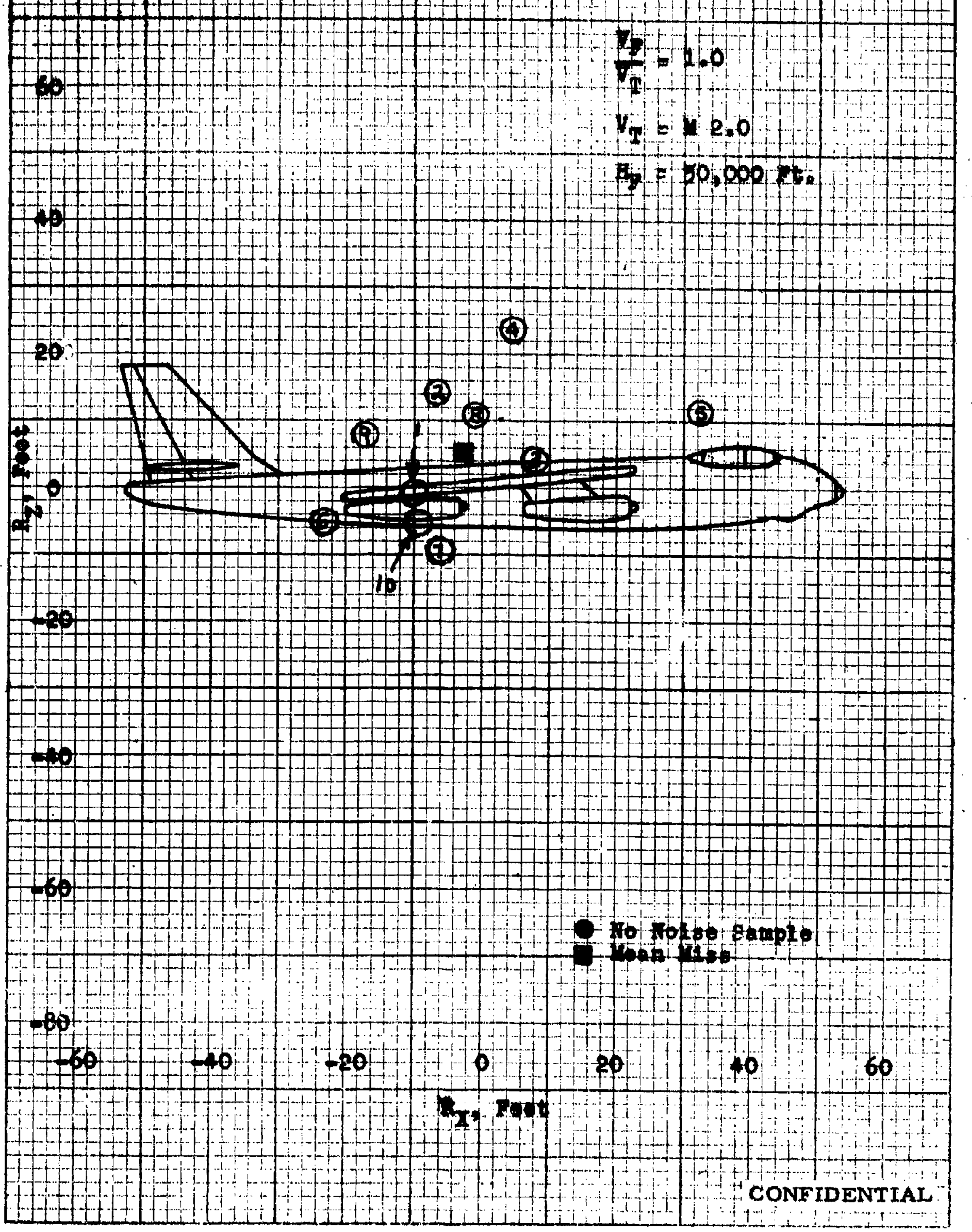

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Fig.17c--Sparrow III Miss Distance - Co-Altitude Attacks
Y-Z Miss Distance at the Target
$T_o = 60°$, Launch $(T_1 + 2)$ sec after R_{Max}
Fighter Course - [illegible]

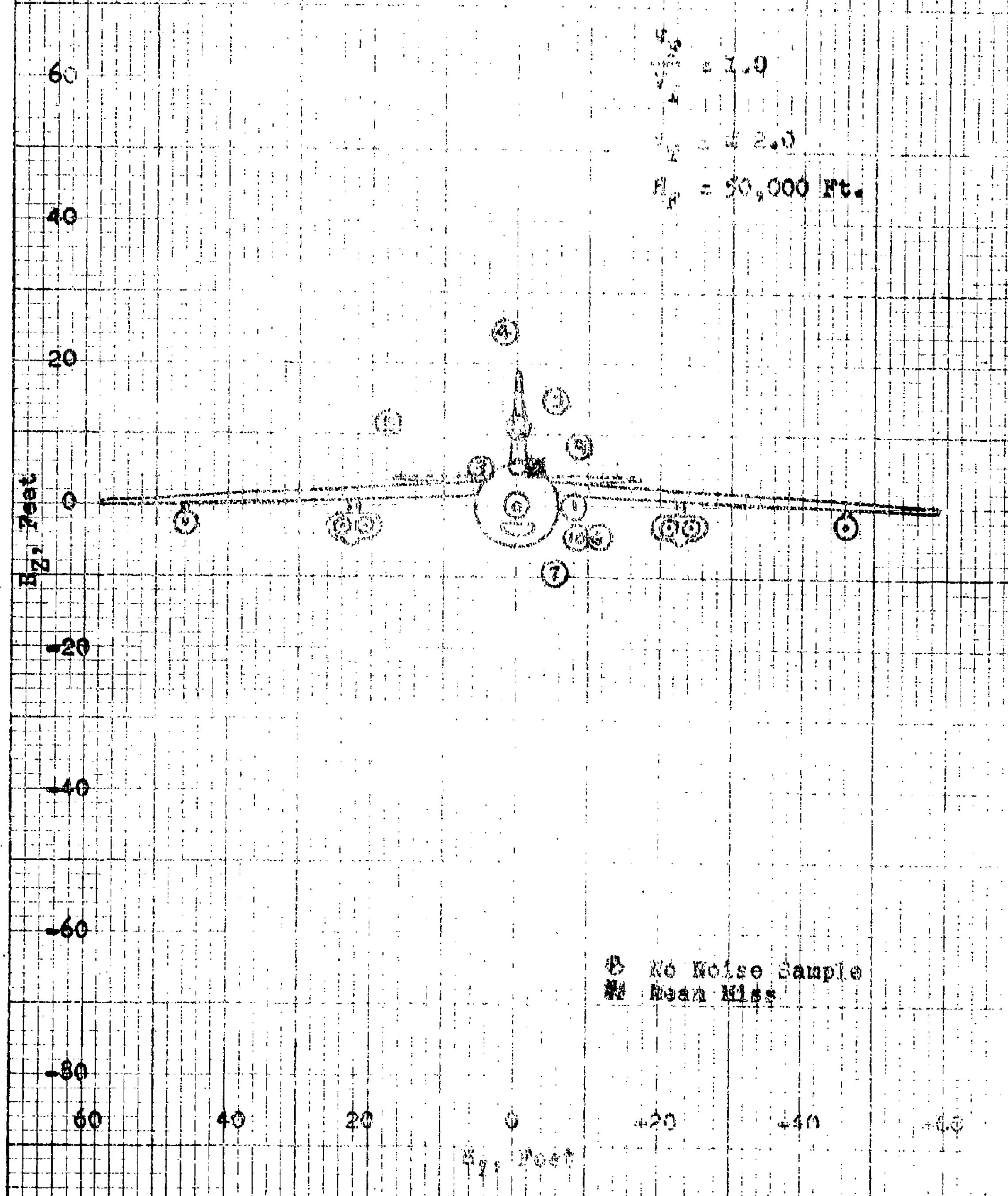

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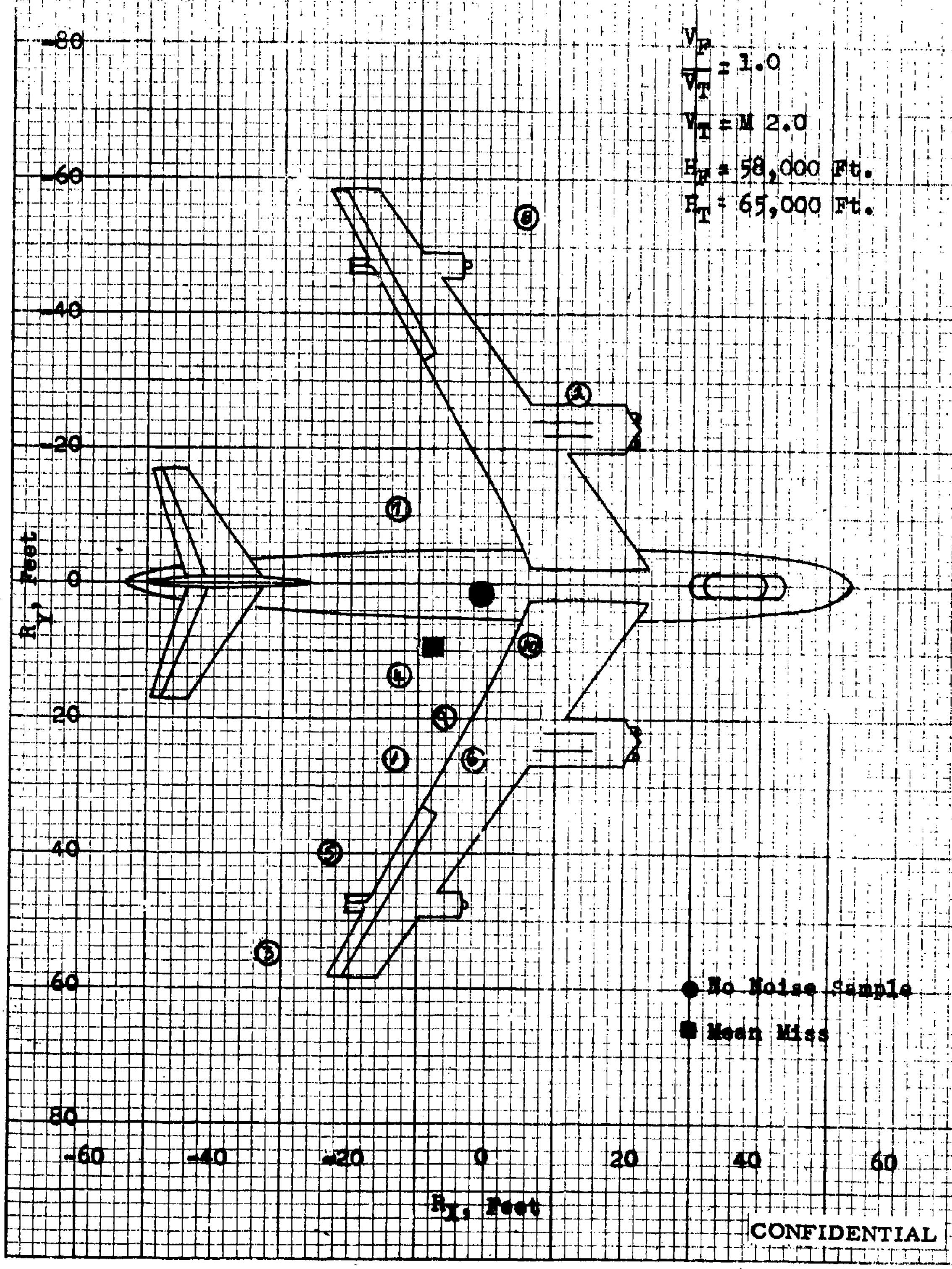
Fig. 18a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$T_L = 0^\circ$, R_{Max} Launch, Fighter Course - D-1



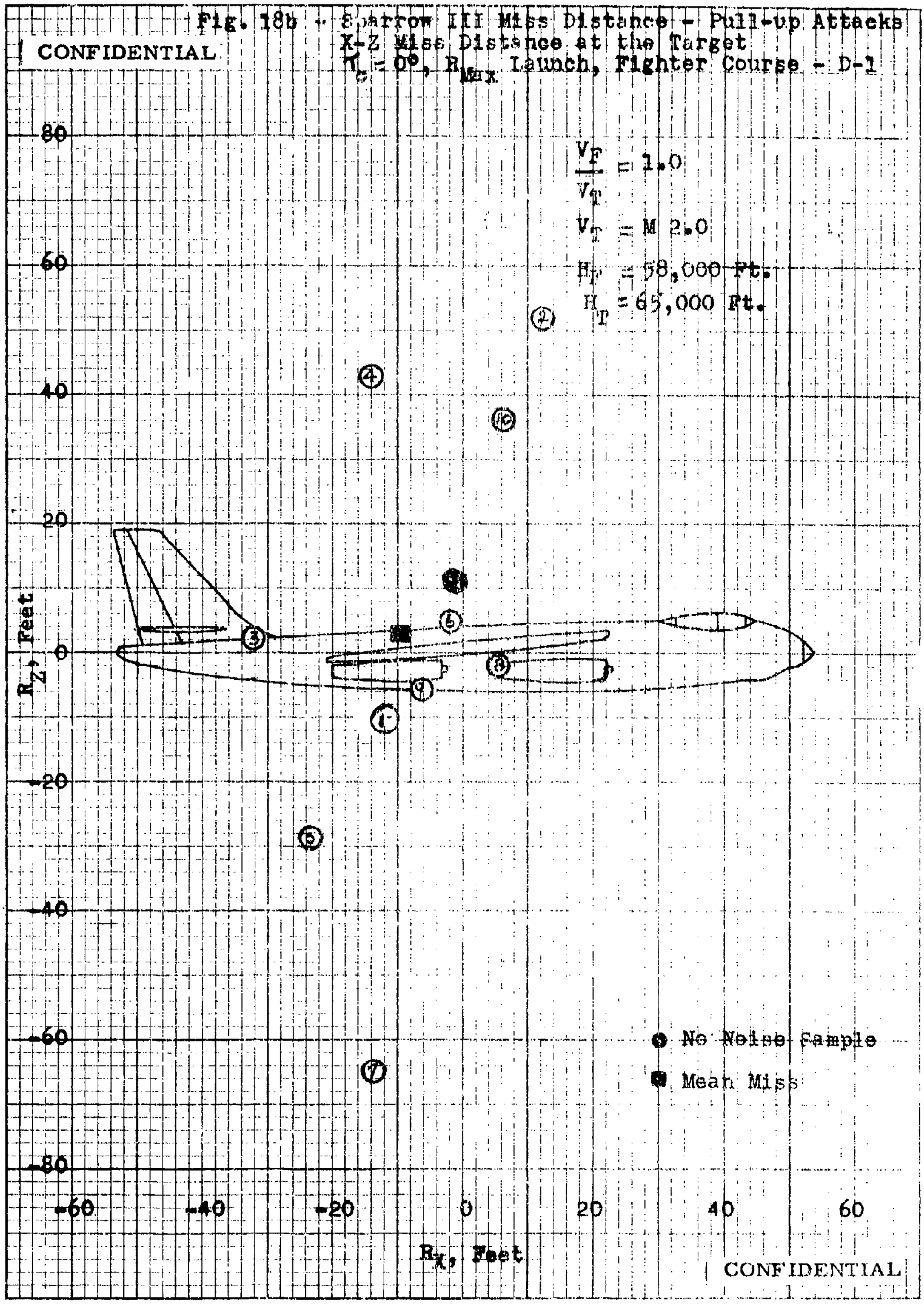


Fig. 18b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\eta_c = 0°$, R_{Max} Launch, Fighter Course - D-1
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$\frac{V_F}{V_T} = 1.0$
V_T = M 2.0
H_F = 58,000 Ft.
H_T = 65,000 Ft.
80
60
40
20
0
-20
-40
-60
-80
R_Z, Feet
-60
-40
-20
0
20
40
60
R_X, Feet
No Noise Sample
Mean Miss
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Fig. 18c - Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\tau_o = 0°$, R_{Max} Launch, Fighter Course - D-1

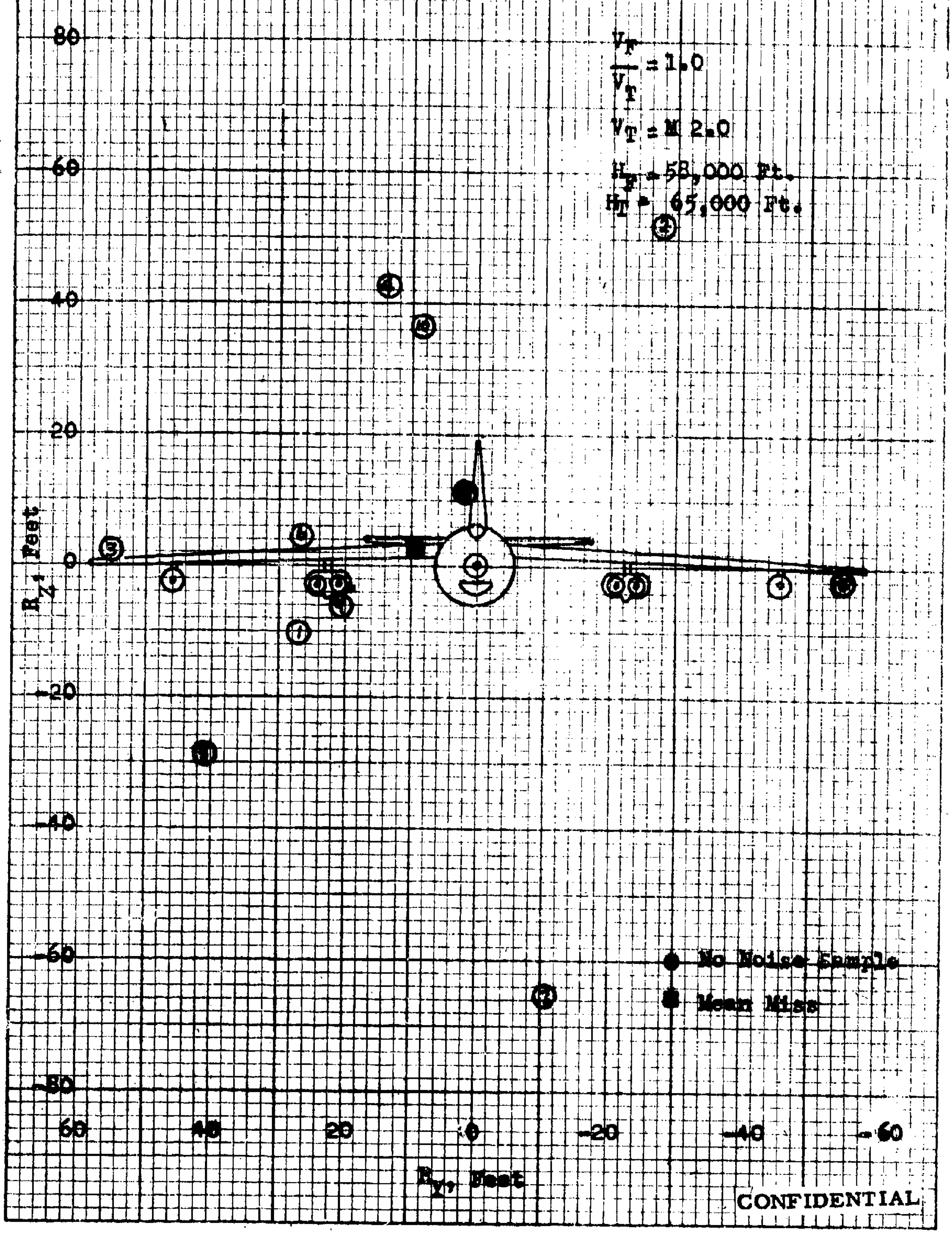

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Fig. 19a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\gamma_o = 0°$, R_{Max} Launch, Fighter Course - C-4

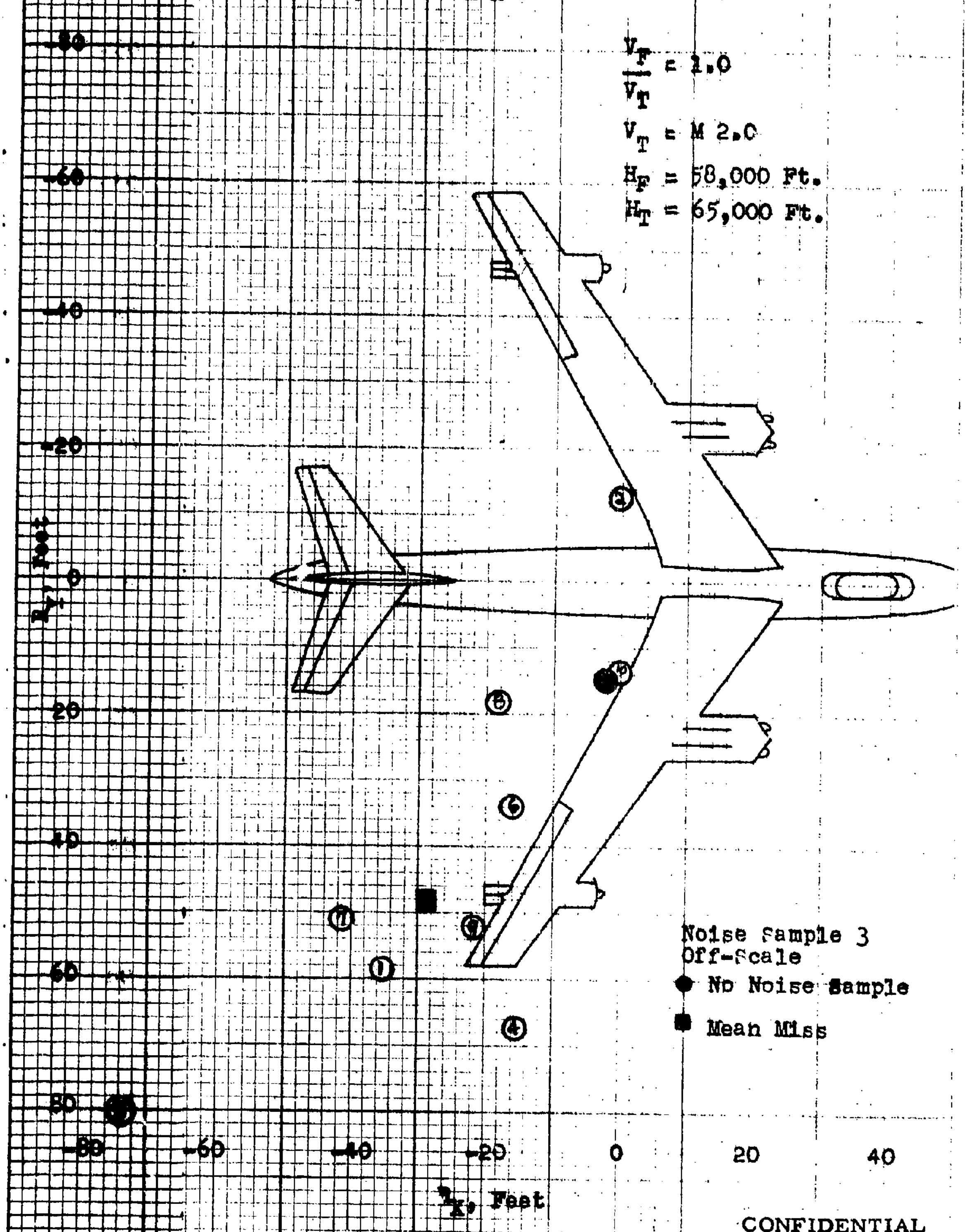

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Fig. 19b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\gamma_o = 0°$, R_{Max} Launch, Fighter Course - C-4

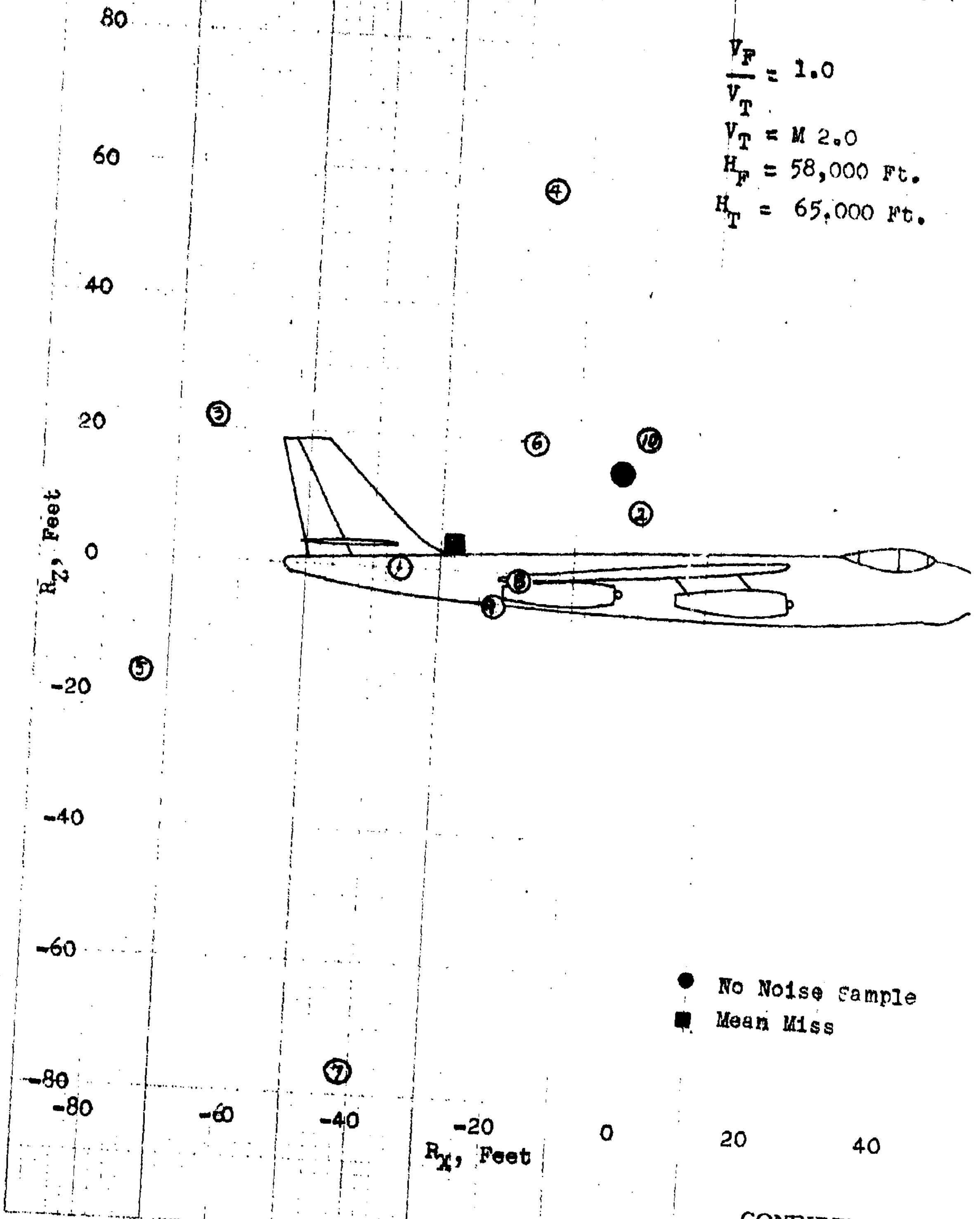

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Fig. 19c - Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\Upsilon_o = 0°$, R_{Max} Launch, Fighter Course - C-4

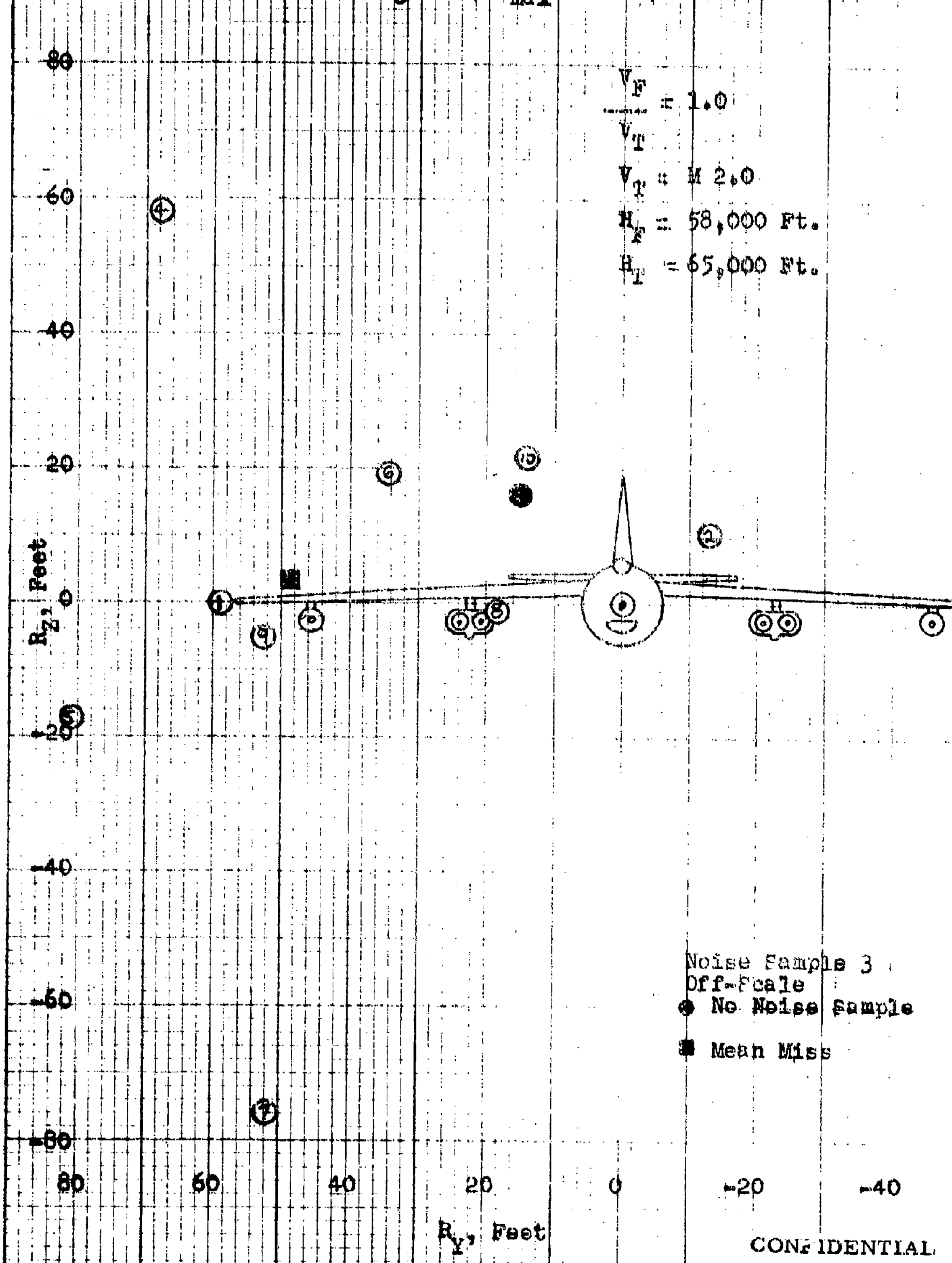

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Fig. 20a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\gamma_0 = 0°$, R_{max} Launch, Fighter Course - D-2

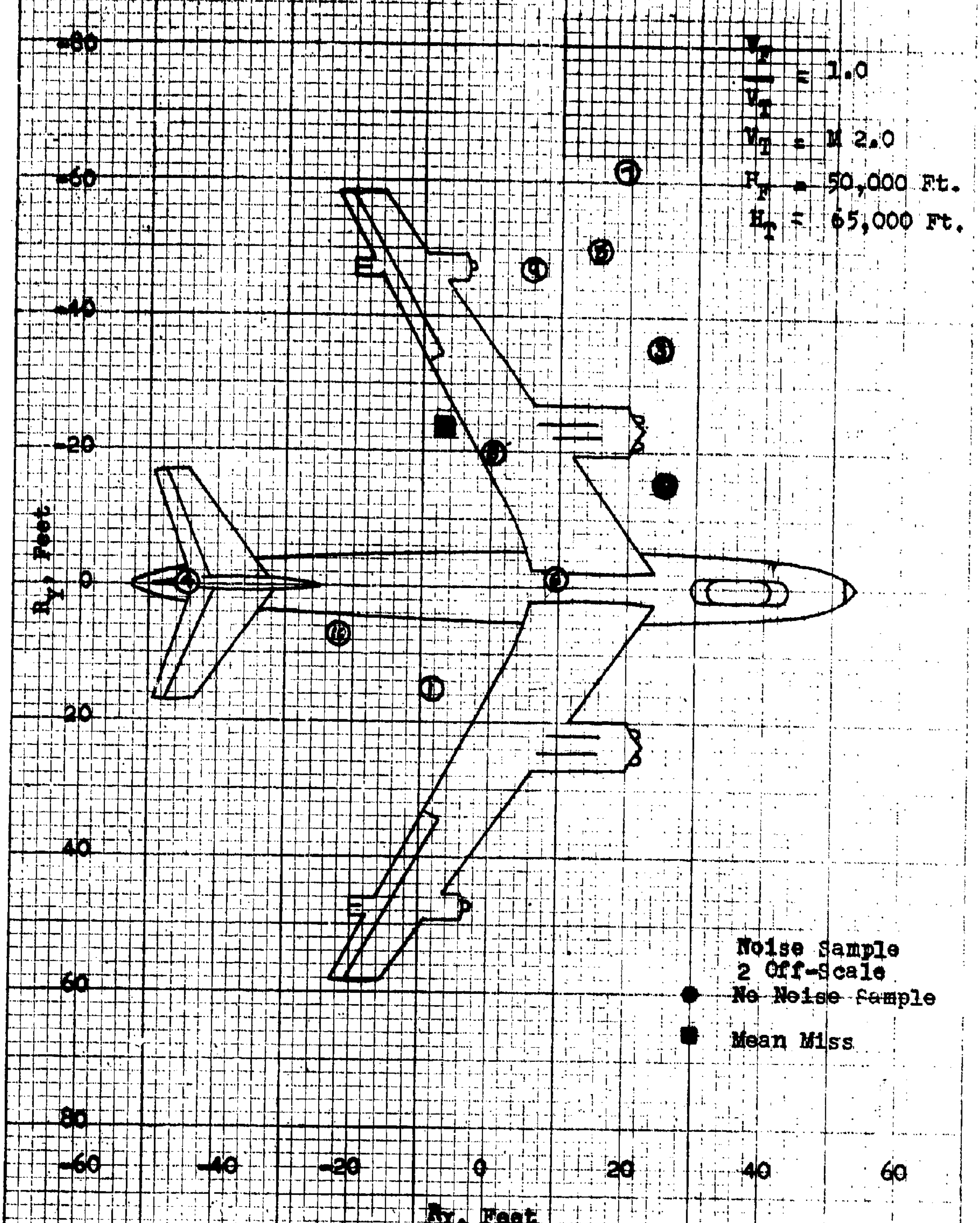

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Fig. 20b Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\gamma_0 = 0^o$, H_{Max} Launch, Fighter Course - D-2

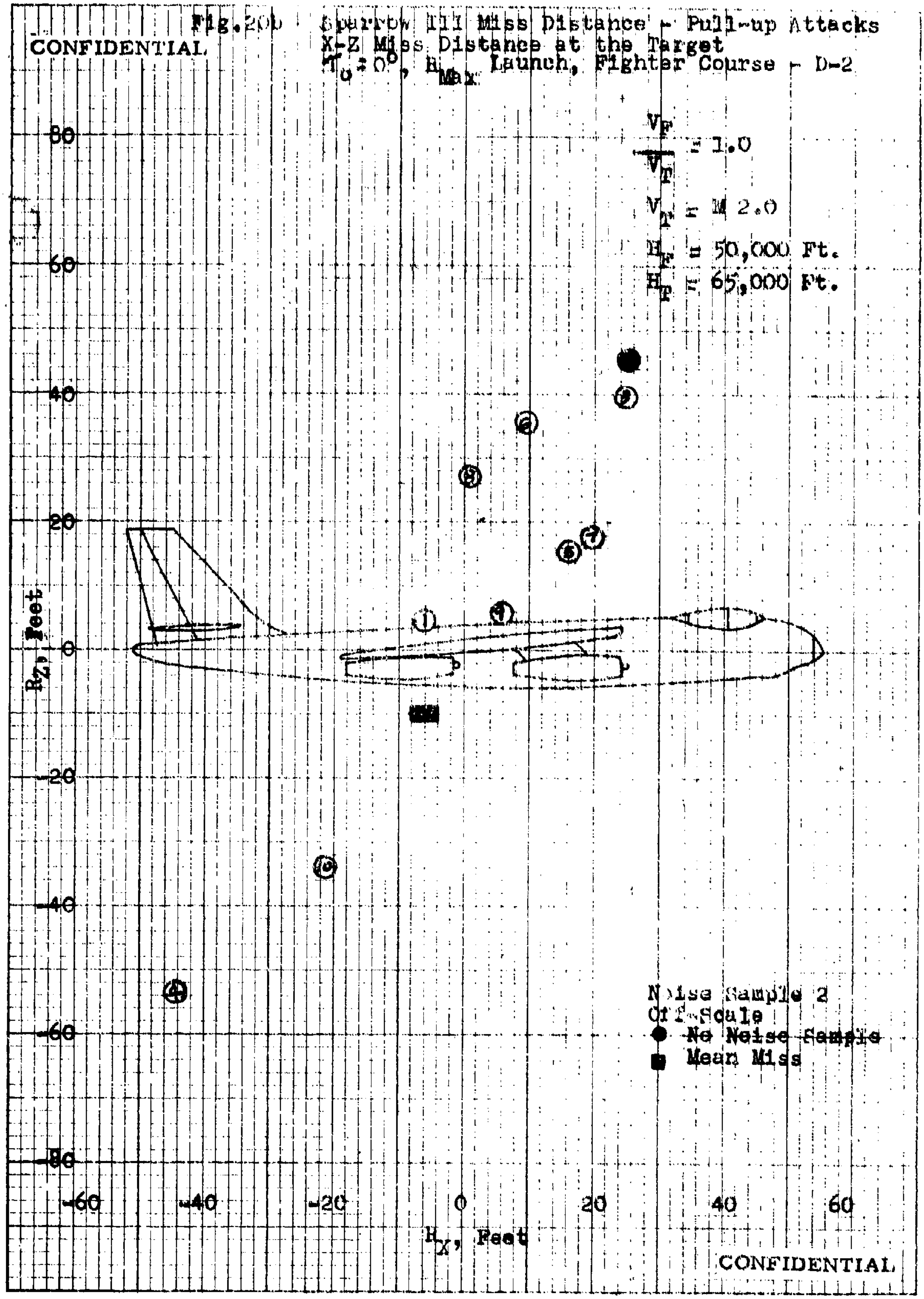

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Fig. 20c - Sparrow III Miss Distance-Pull-up Attacks
Y-Z Miss Distance at the Target
$\gamma_D = 0^{\circ}$, R_{Max} Launch, Fighter Course - D-2

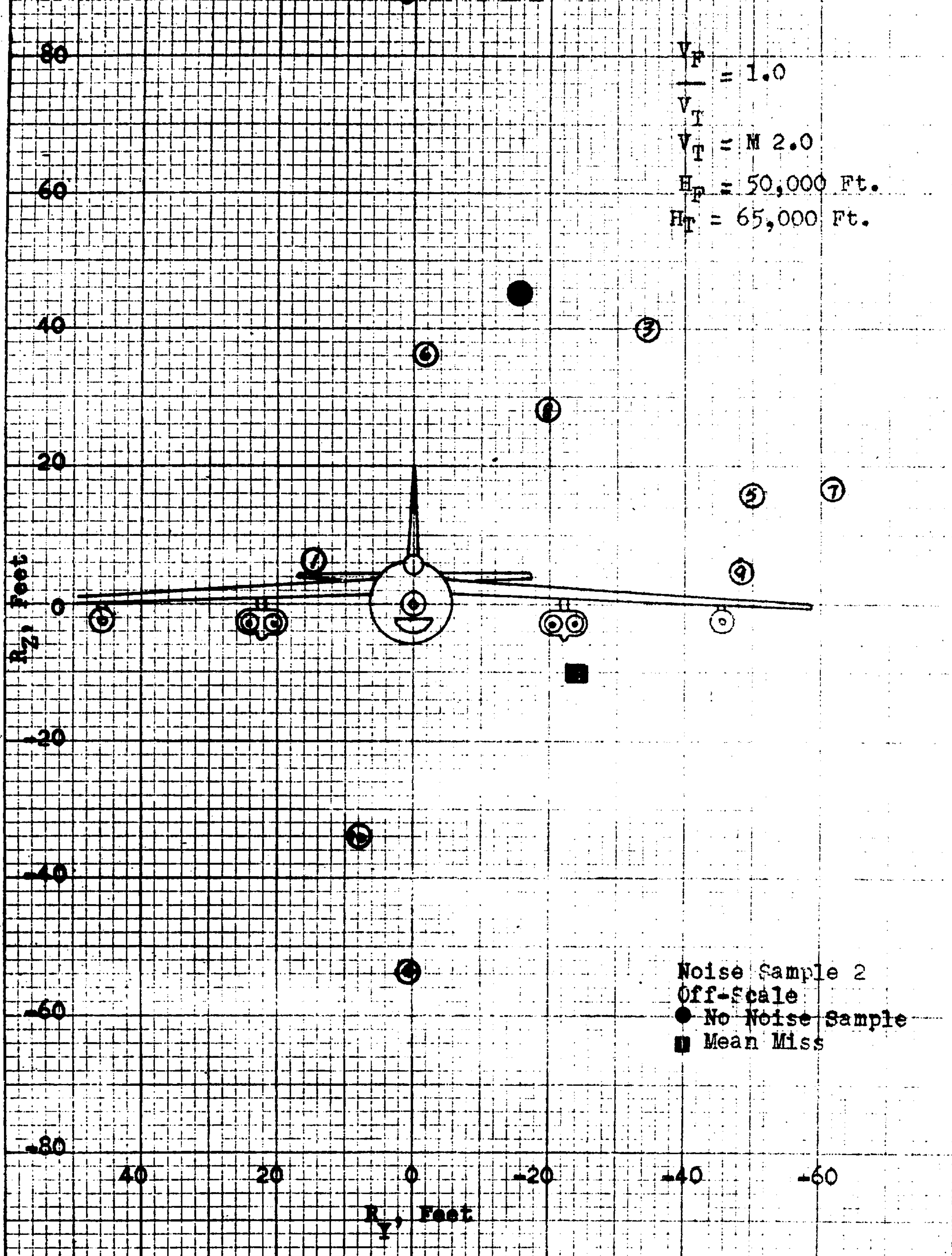

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Fig. 21a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\sigma_o = 0^o$, R_{max} Launch, Fighter Course - C-5

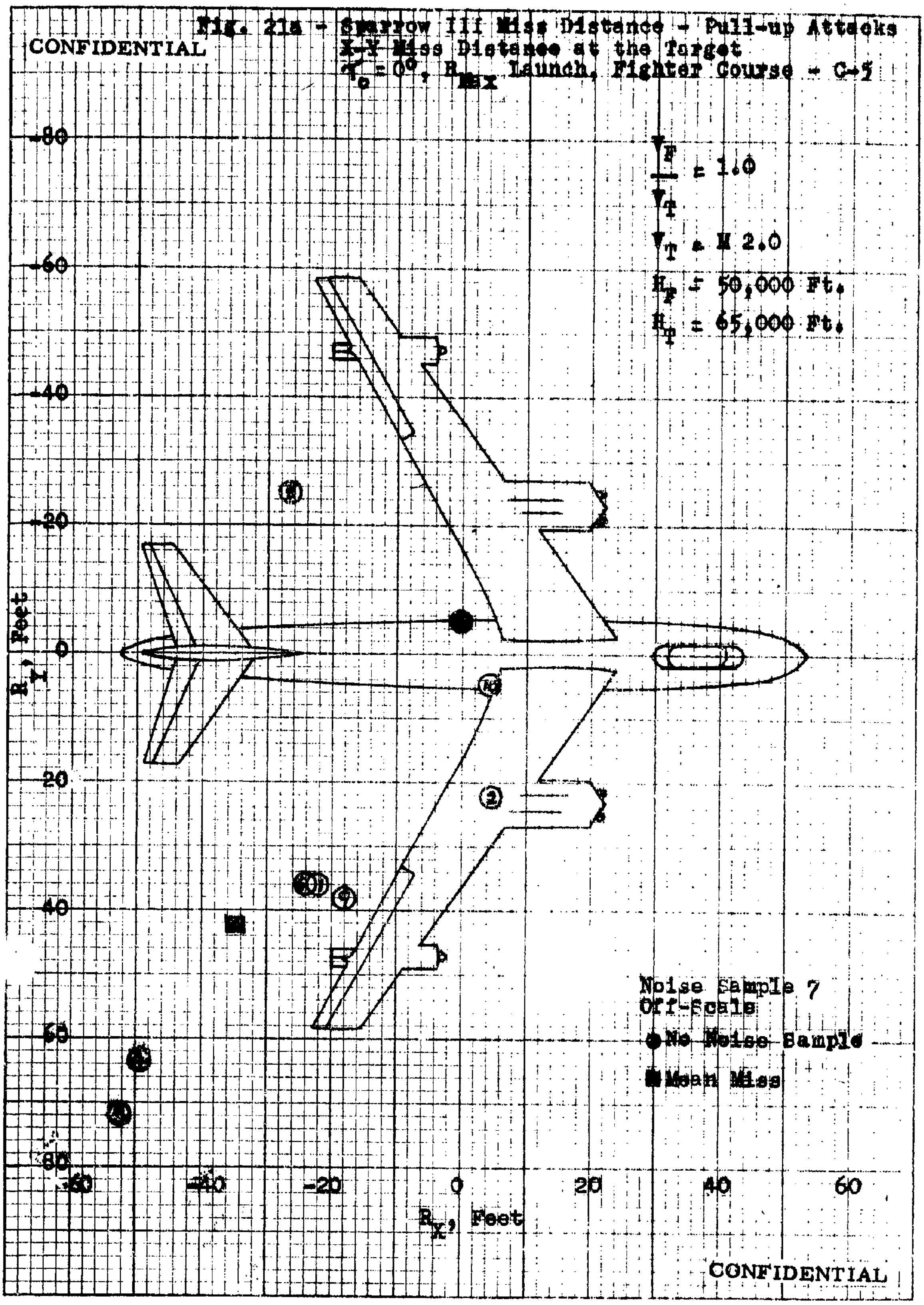

Fig. 21b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\Gamma_o = 0^o$, R_{Max} Launch, Fighter Course - C-5

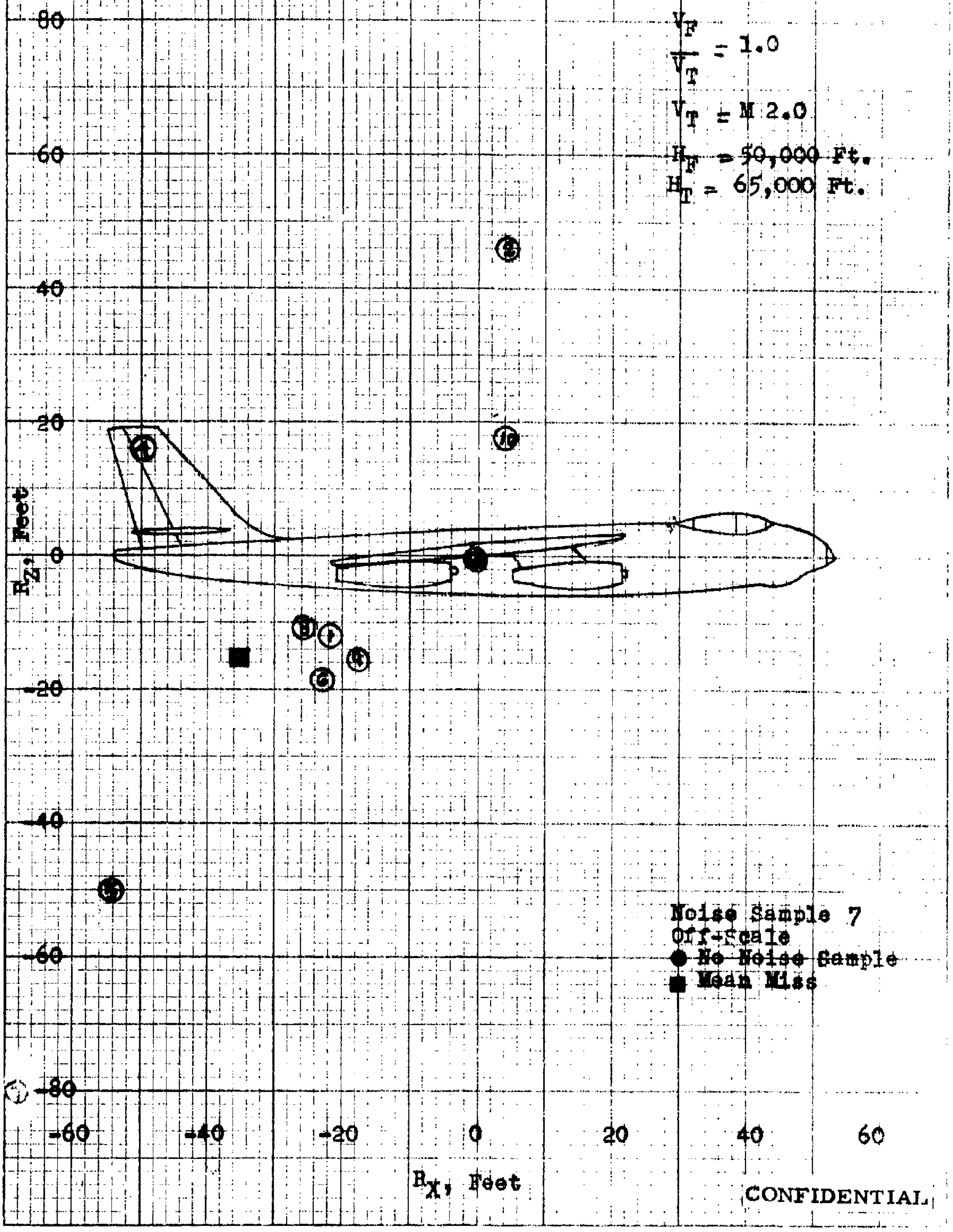

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Fig. 21c - Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\tau_o = 0^o$, R_{Max} Launch, Fighter Course - C-5

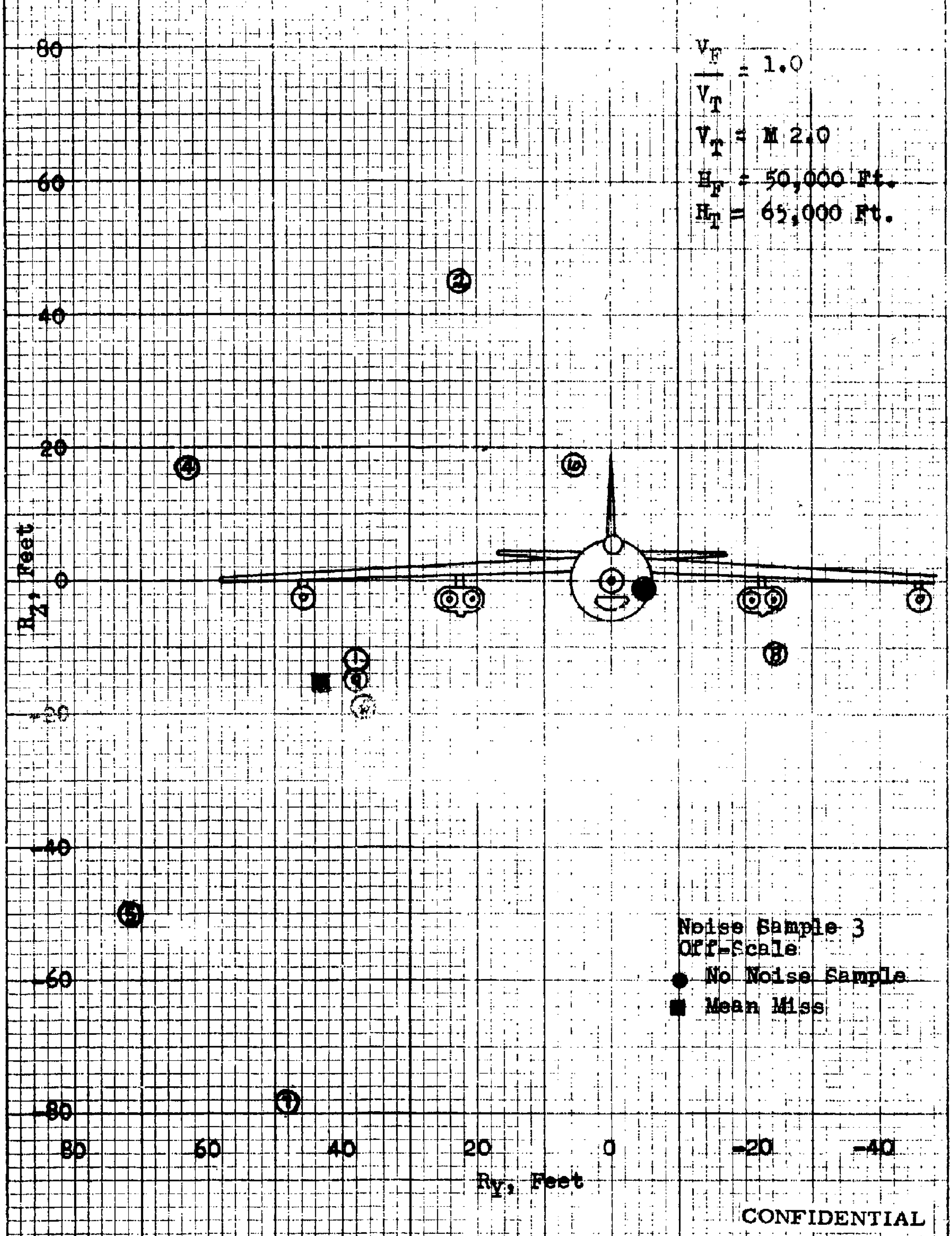

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Fig. 22a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\gamma_o = 45°$, R_{Max} Launch, Fighter Course - D-1

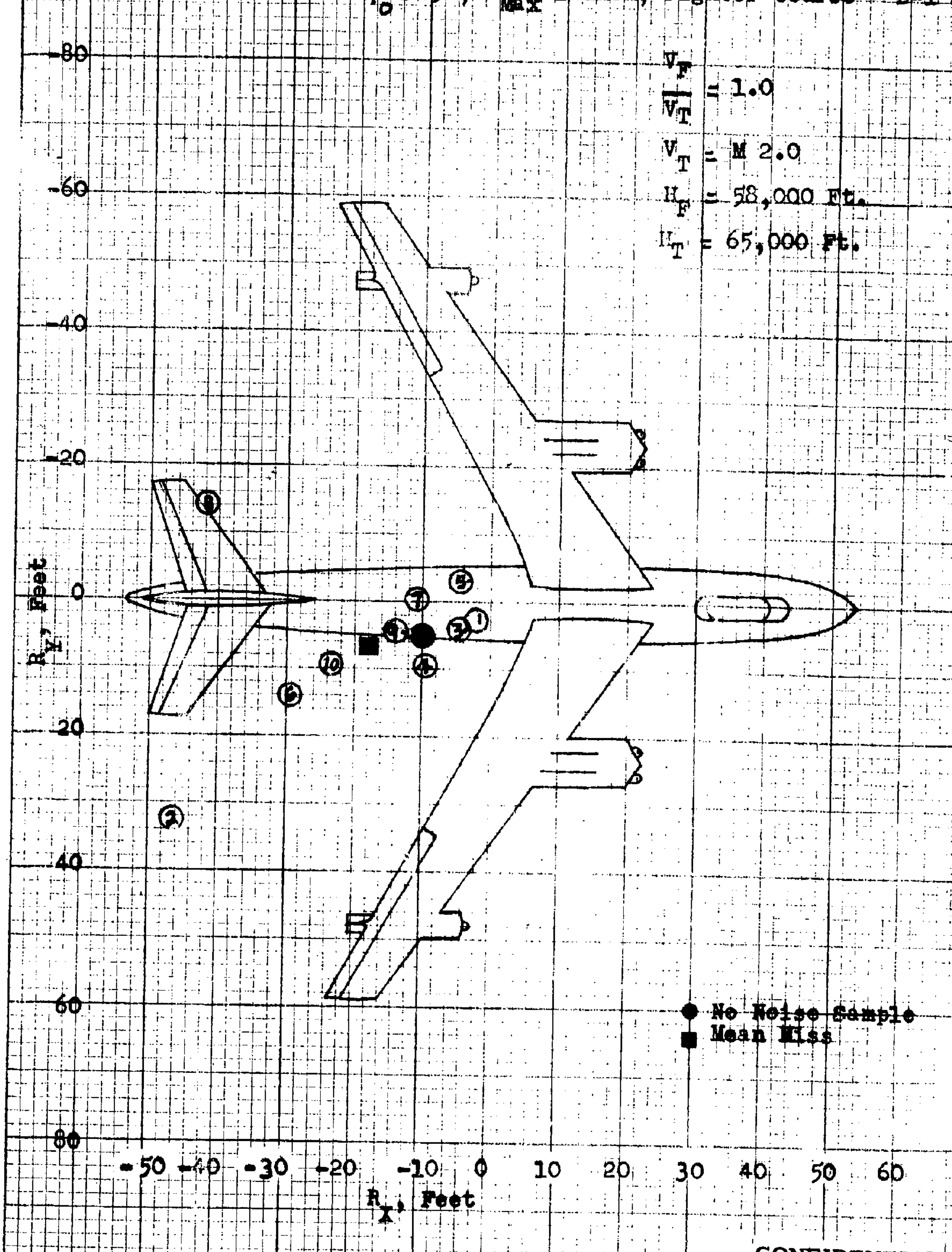

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Fig. 22b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\tau_b = 45^o$, R_{Max} Launch, Fighter Course - D-1

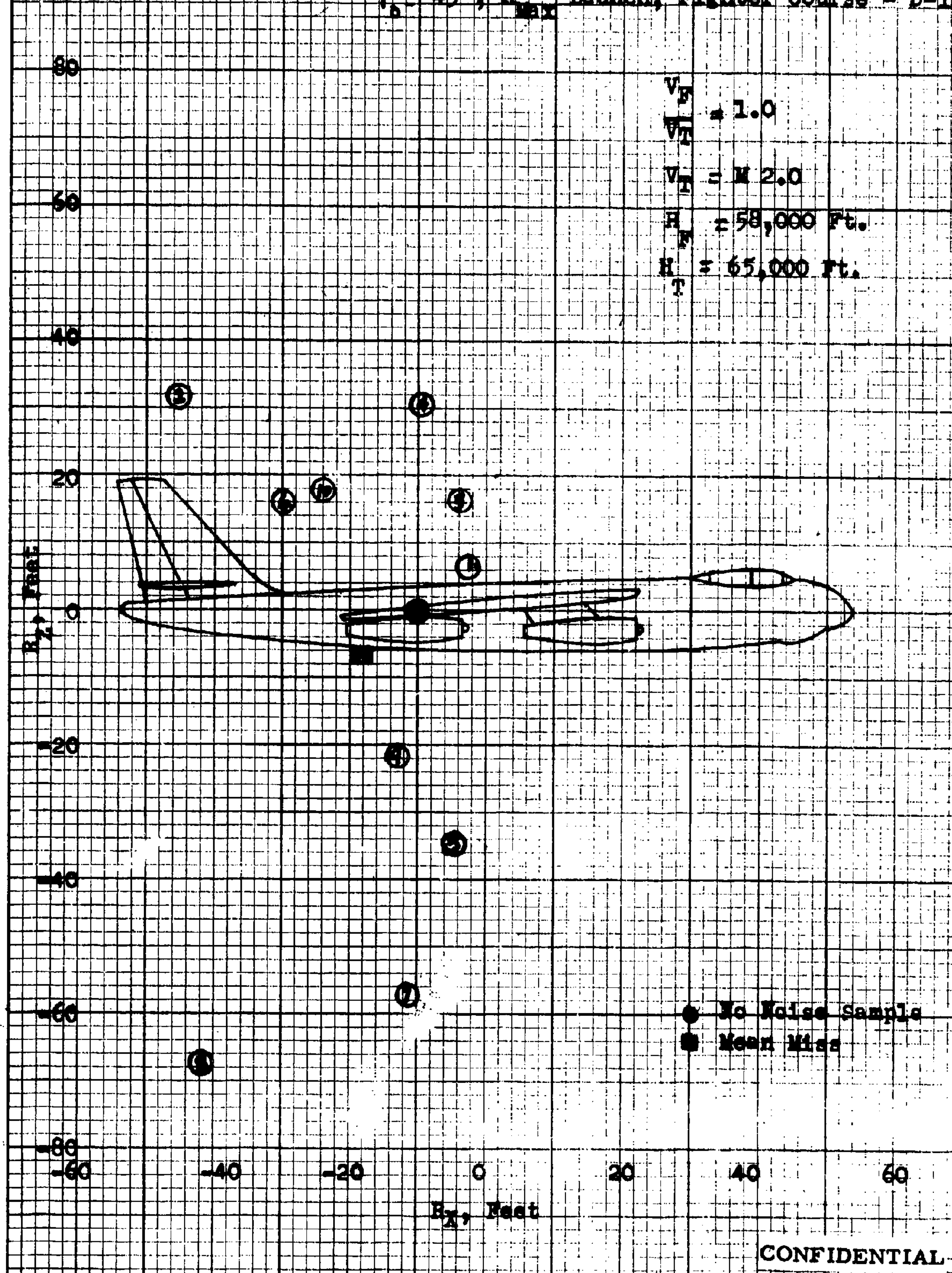

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Fig. 22c - Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\epsilon_0 = 45°$, R_{max} Launch, Fighter Course - D-1

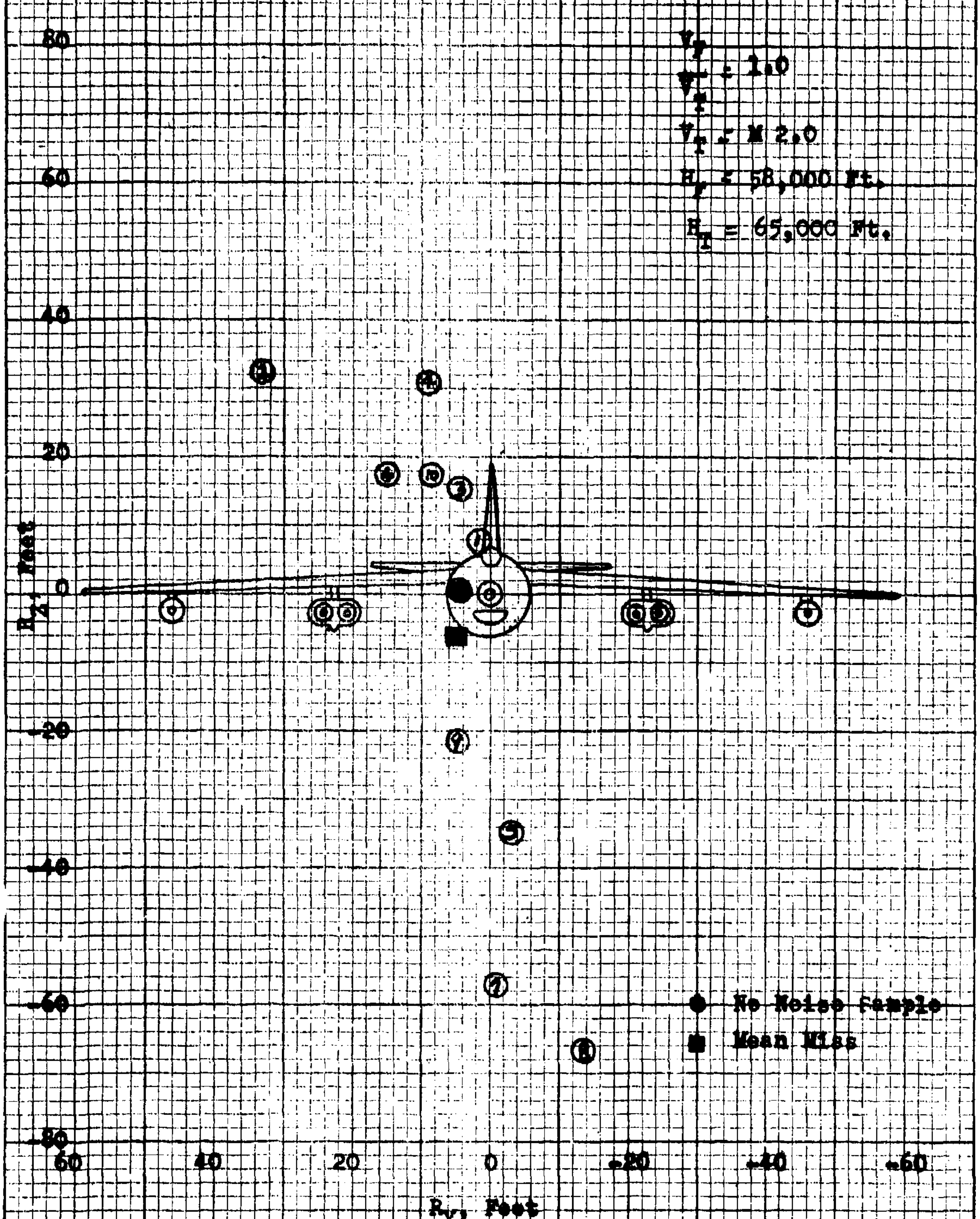

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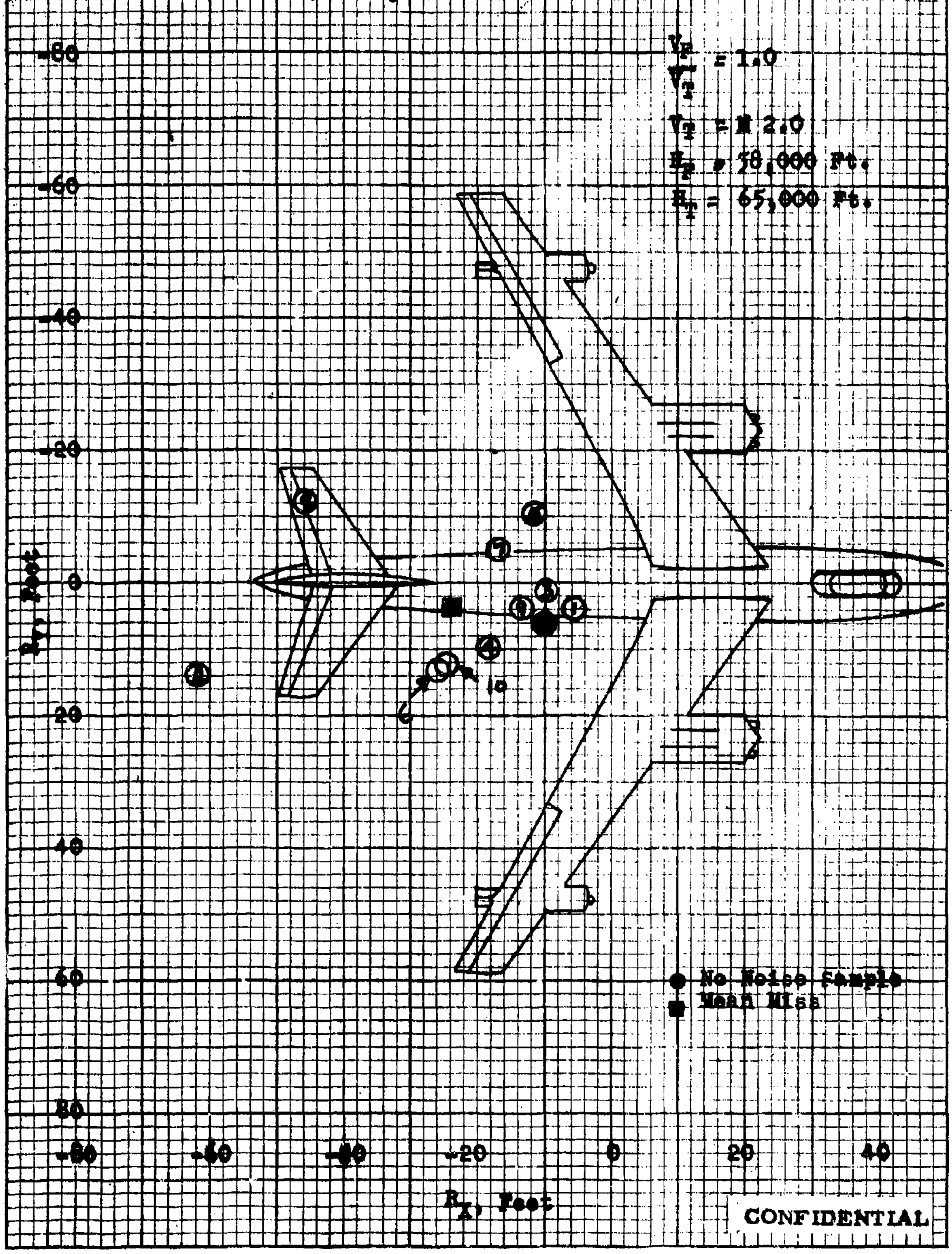
Fig. 23a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\gamma_o = 45°$, R_{Max} Launch, Fighter Course - E-4



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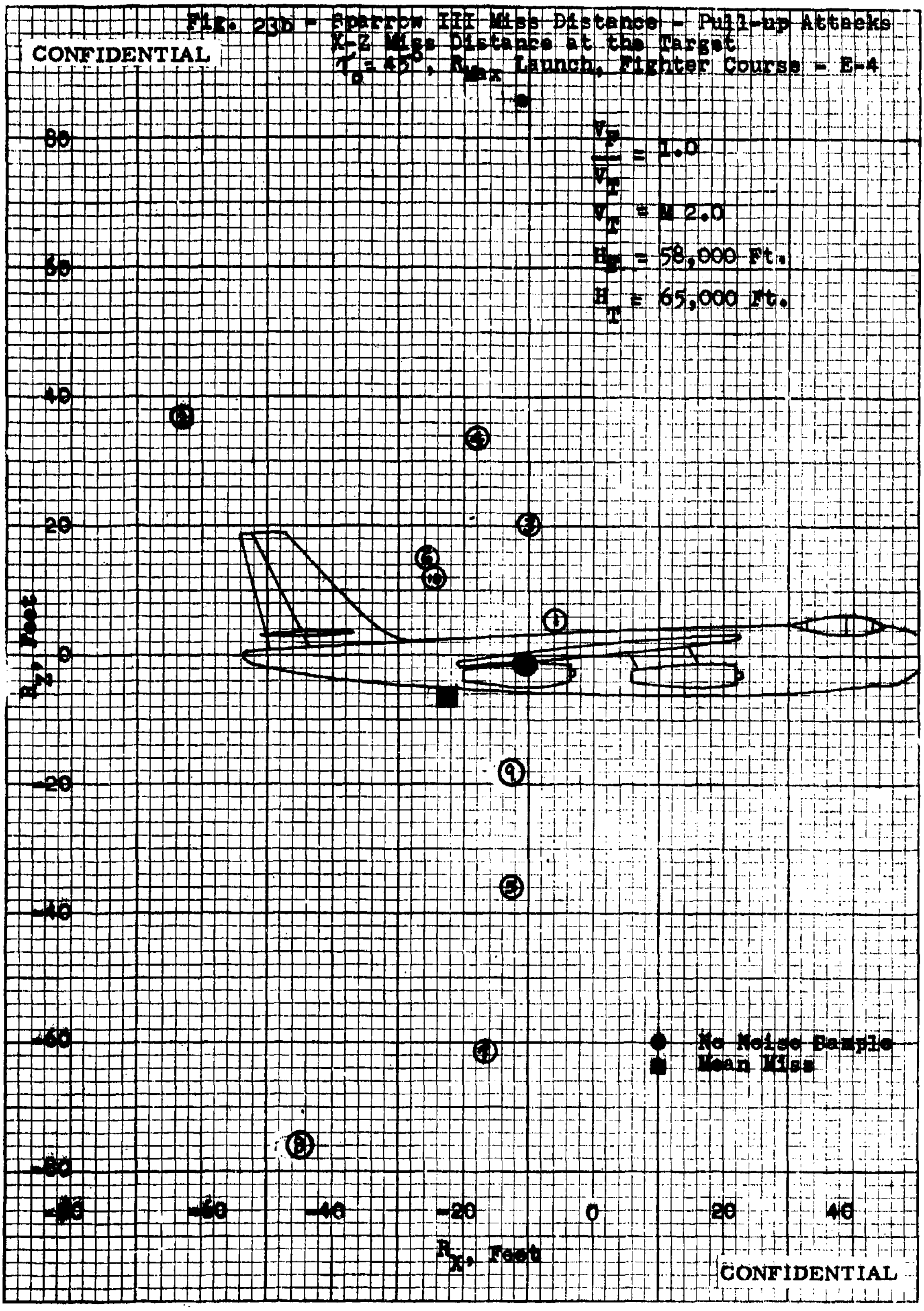

Fig. 23b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\tau_o = 45^\circ$, R_{Max} Launch, Fighter Course - E-4

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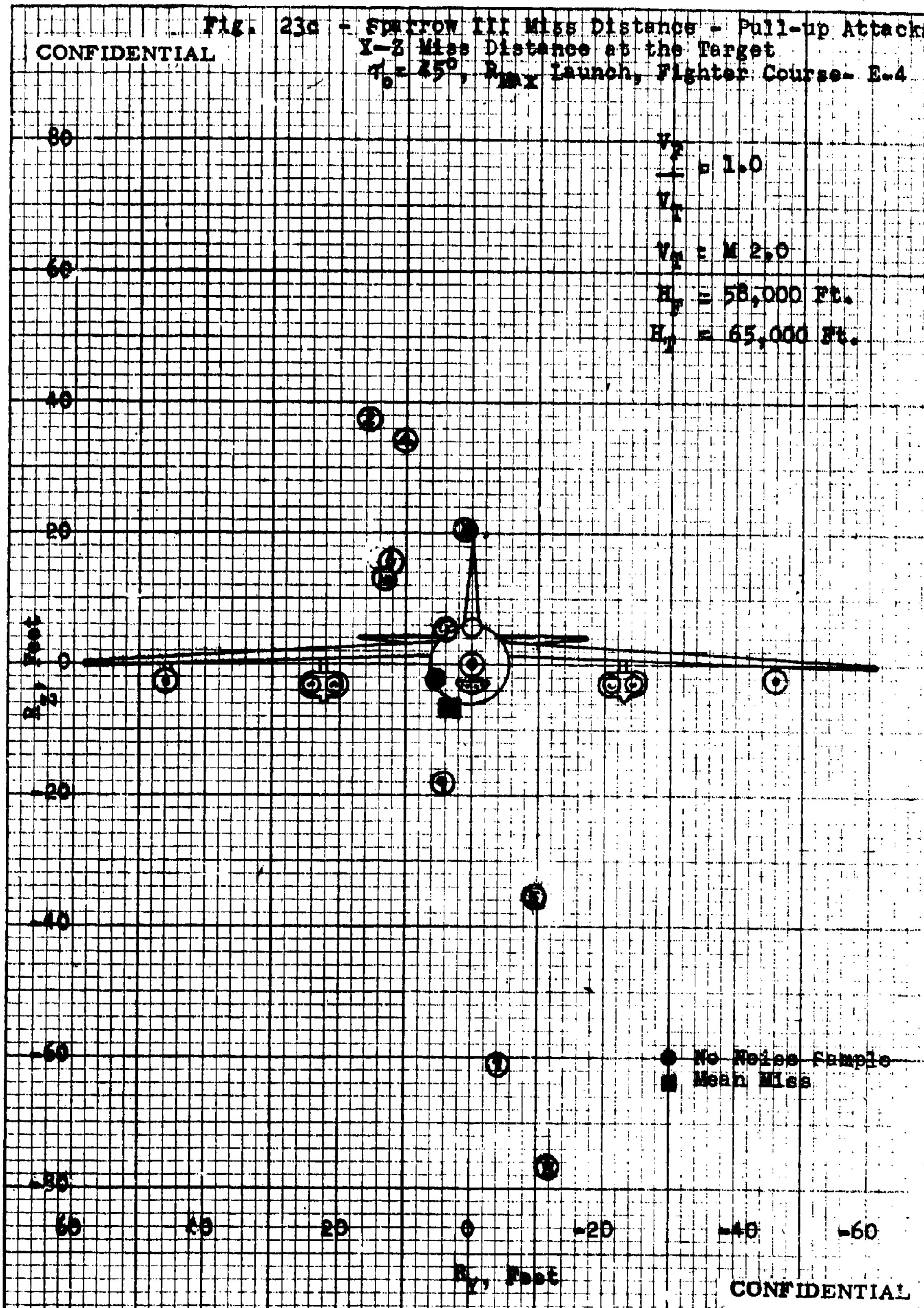

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Fig. 24a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\gamma_0 = 45^0$, R_{Max} Launch, Fighter Course - D-1

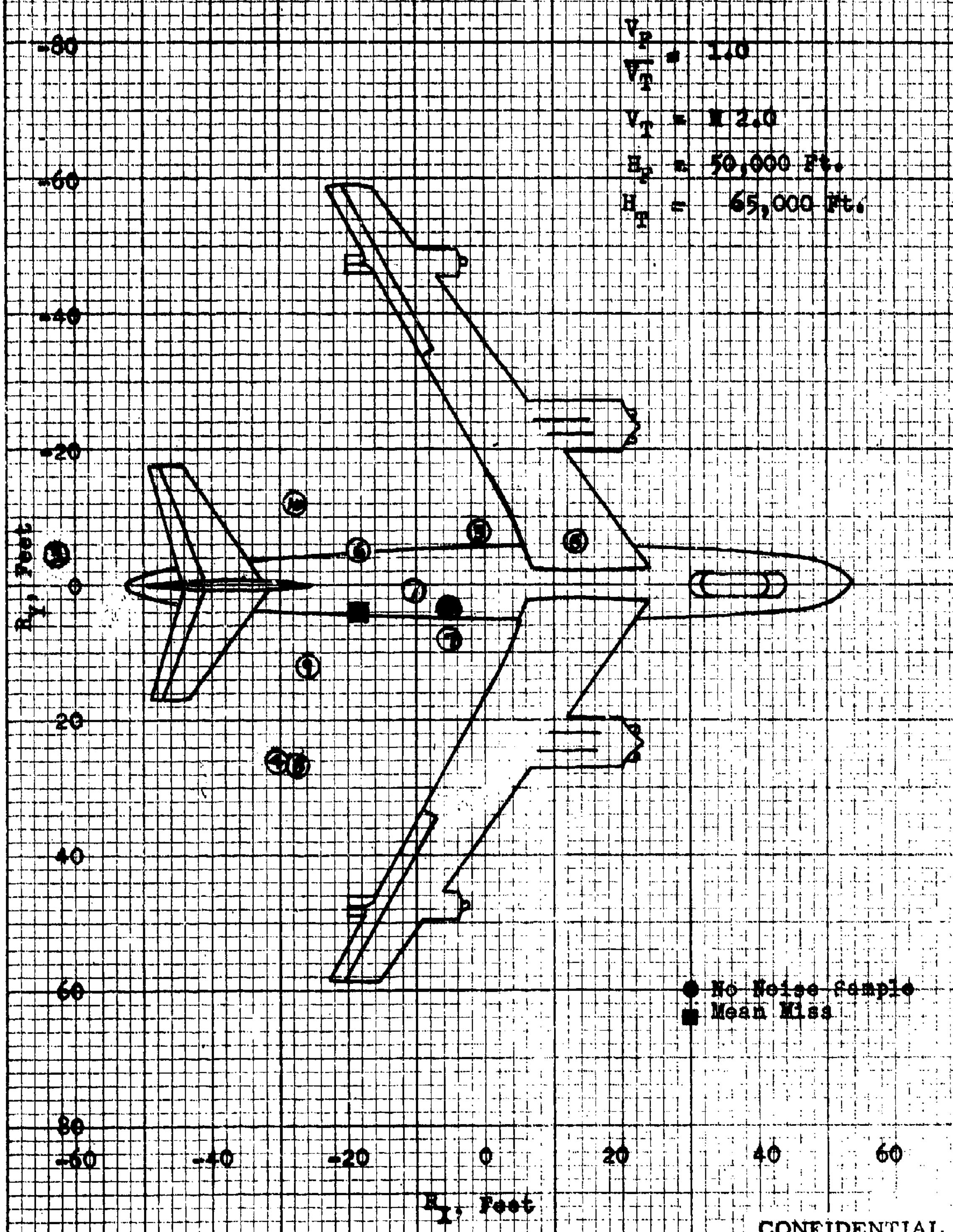

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Fig. 24b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\Upsilon_0 = 45°$, R_{Max} Launch - Fighter Course - D-1

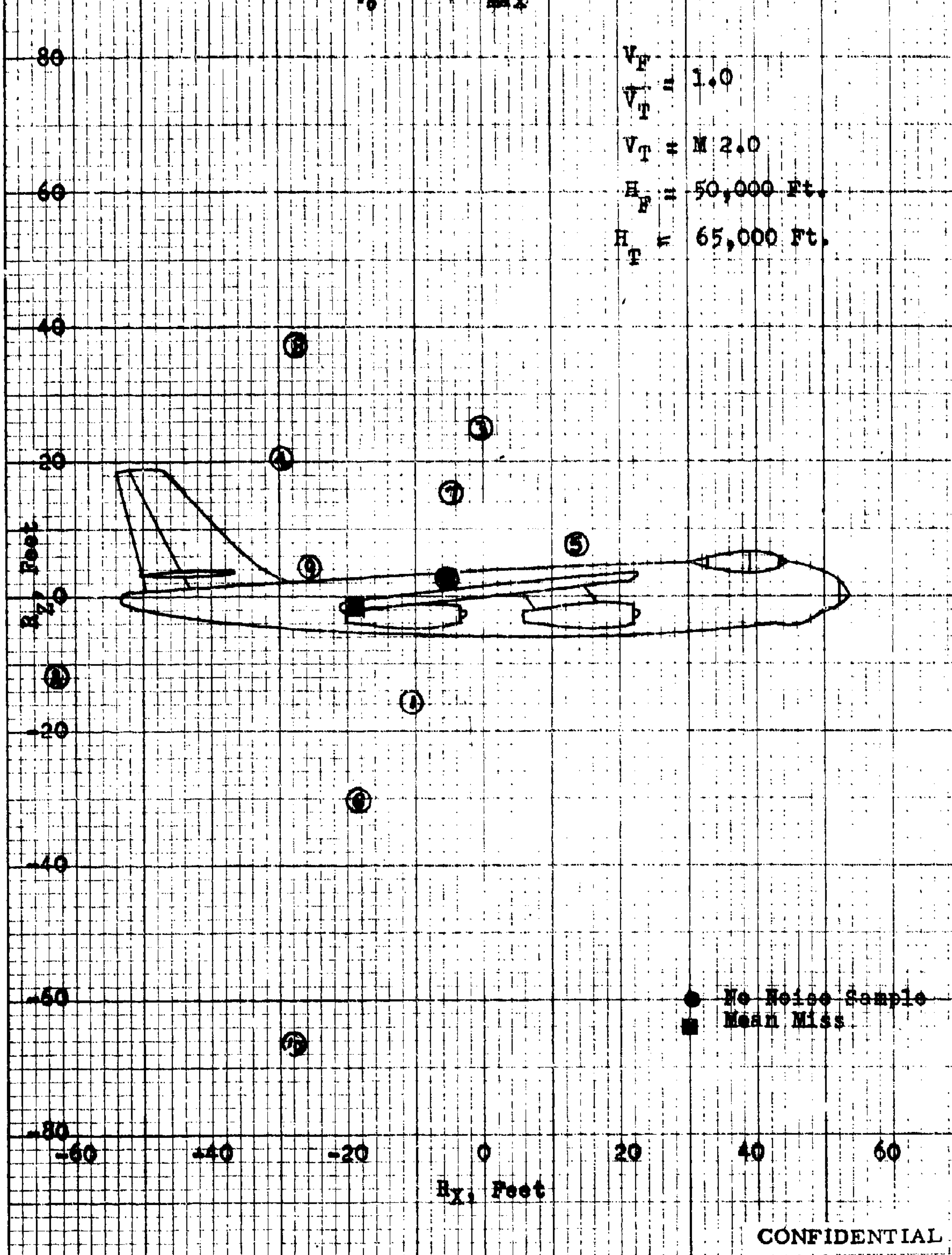

Fig. 24c - Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\gamma_s = 45°$, R_{max} Launch, Fighter Course - D-1

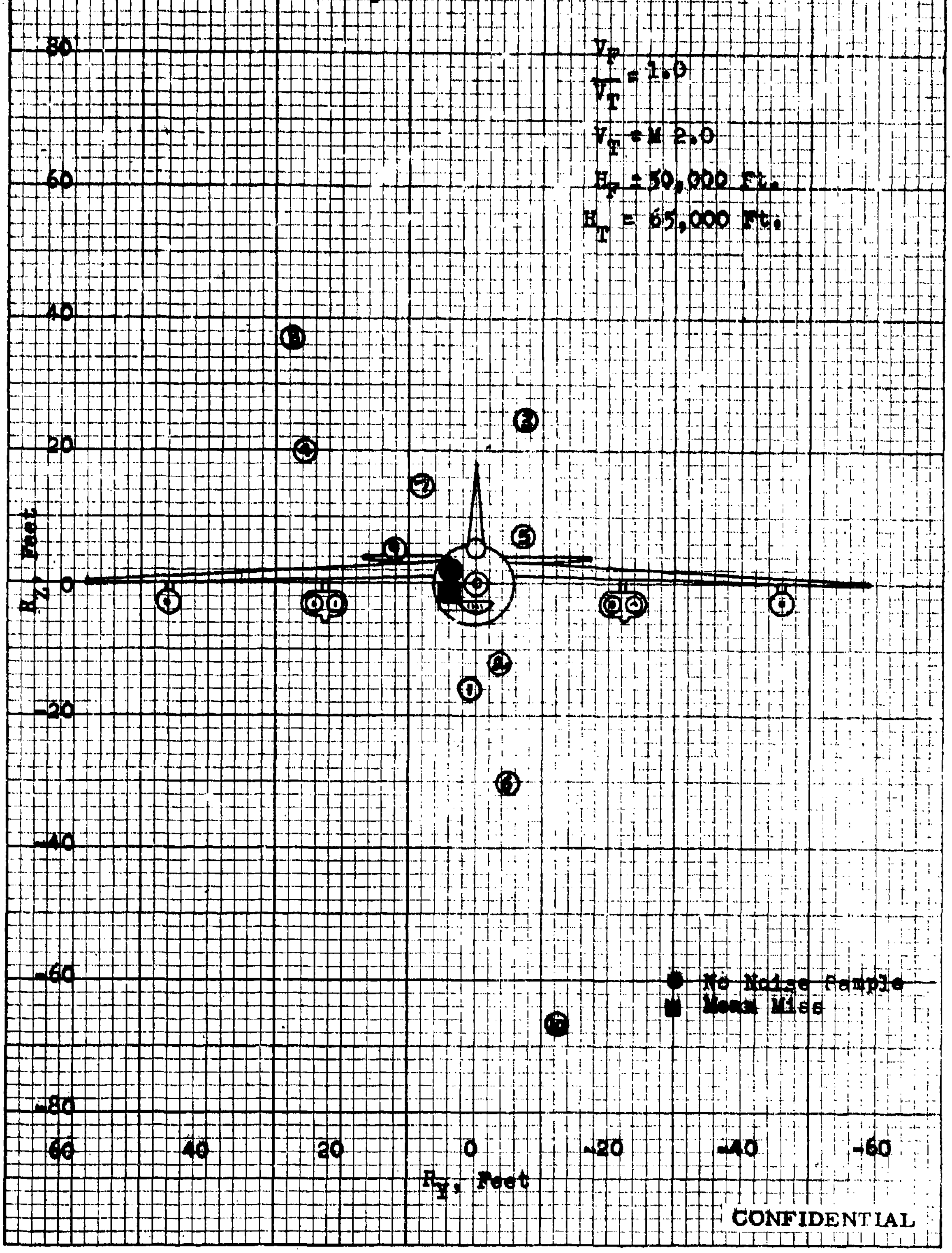

Fig. 25a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\Gamma_o = 45^\circ$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch,
Fighter Course - D-1

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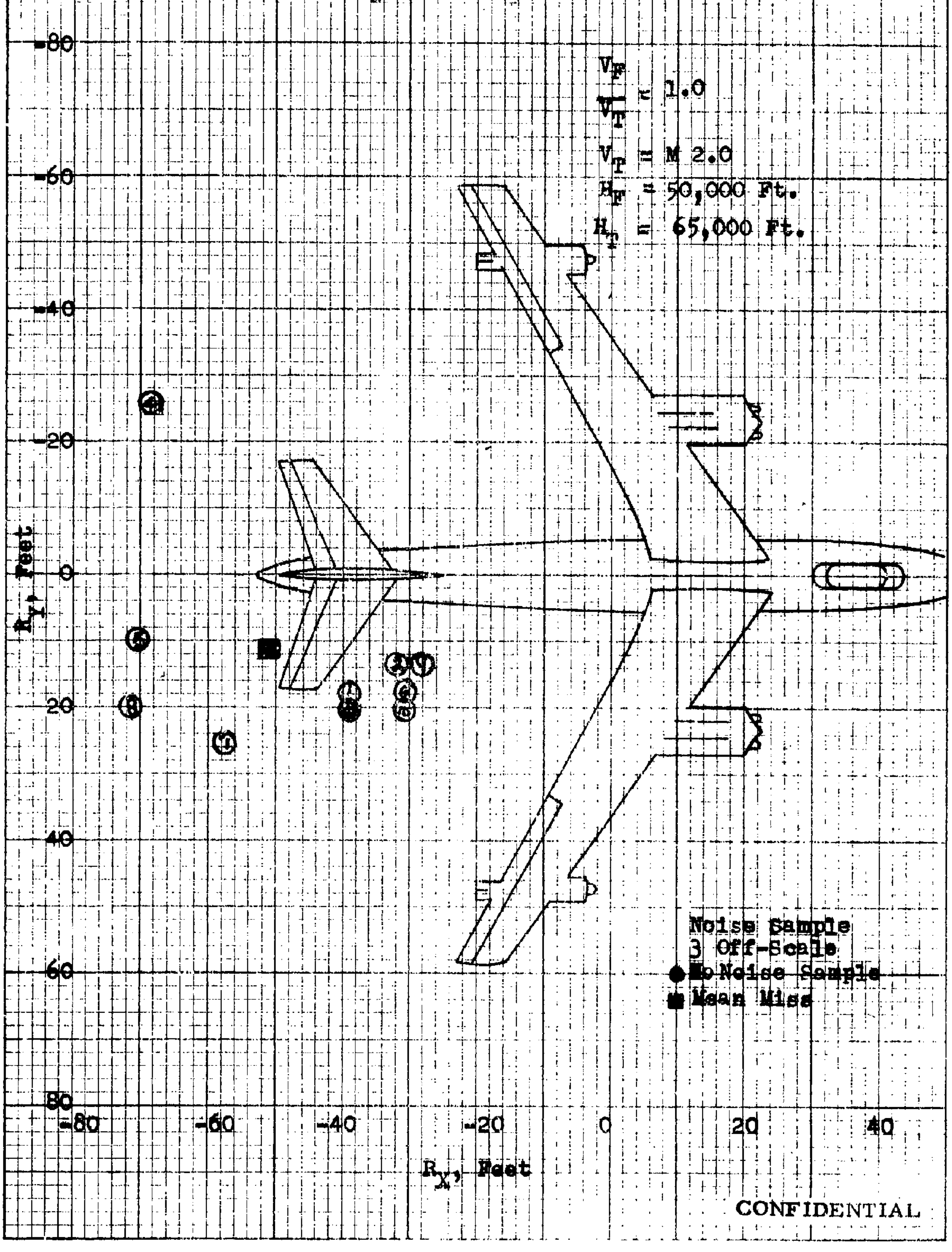

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Fig. 25b - Sparrow III Miss Distance - Pull-up Attack
X-Z Miss Distance at the Target
$\tau_o = 45^\circ$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch,
Fighter Course - D-1

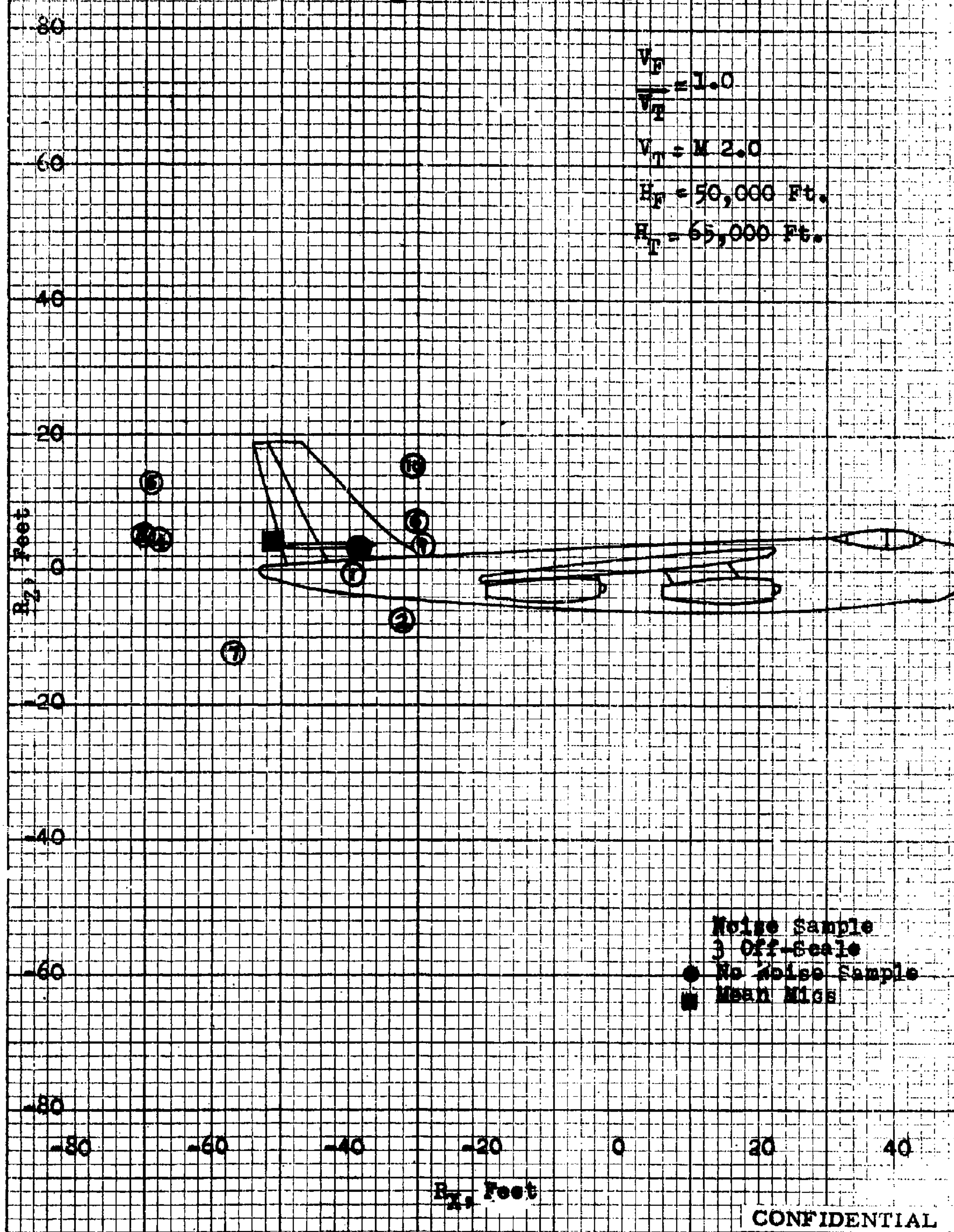

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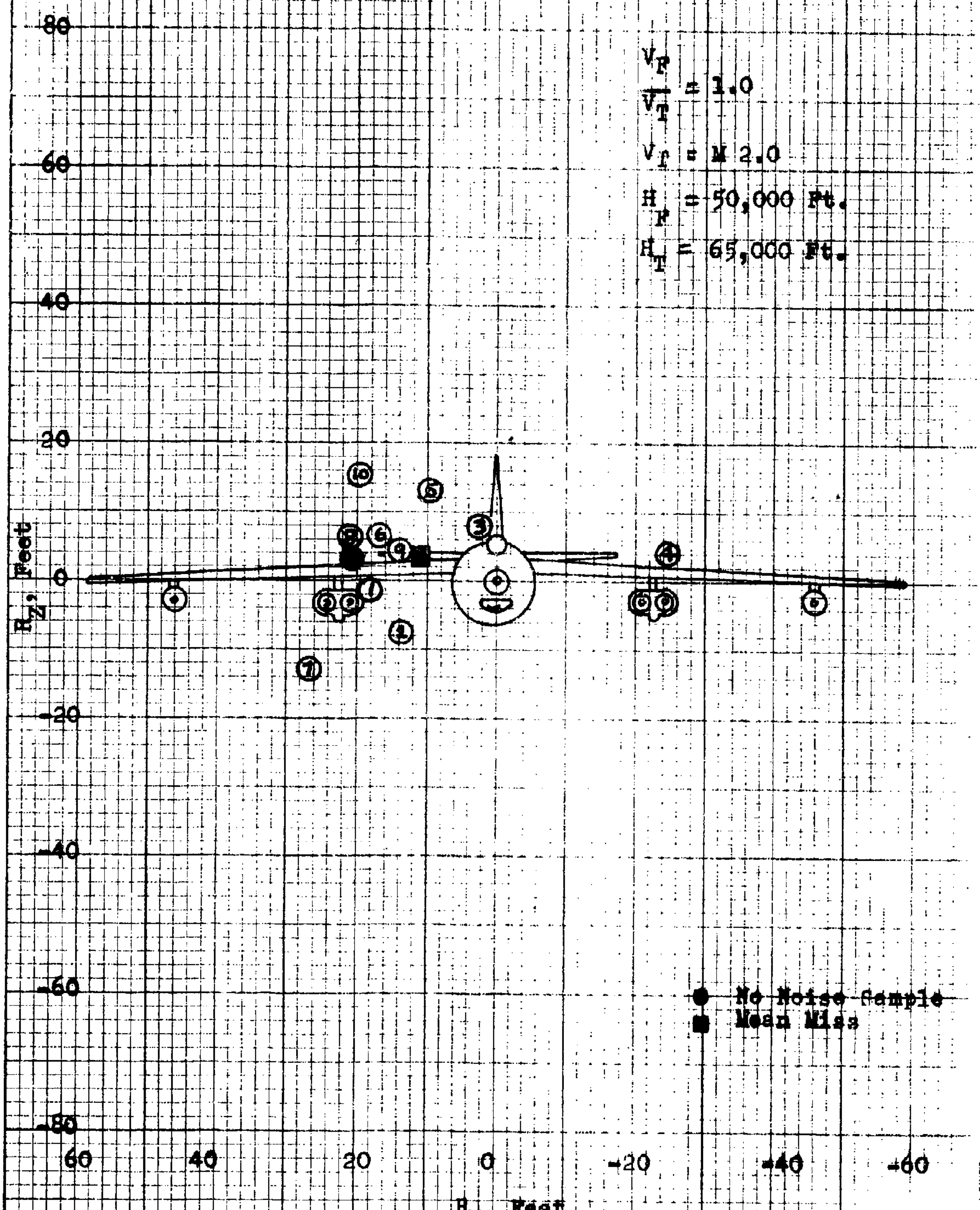
Fig. 25c - Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\tau_o = 45^\circ$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch,
Fighter Course - D-1



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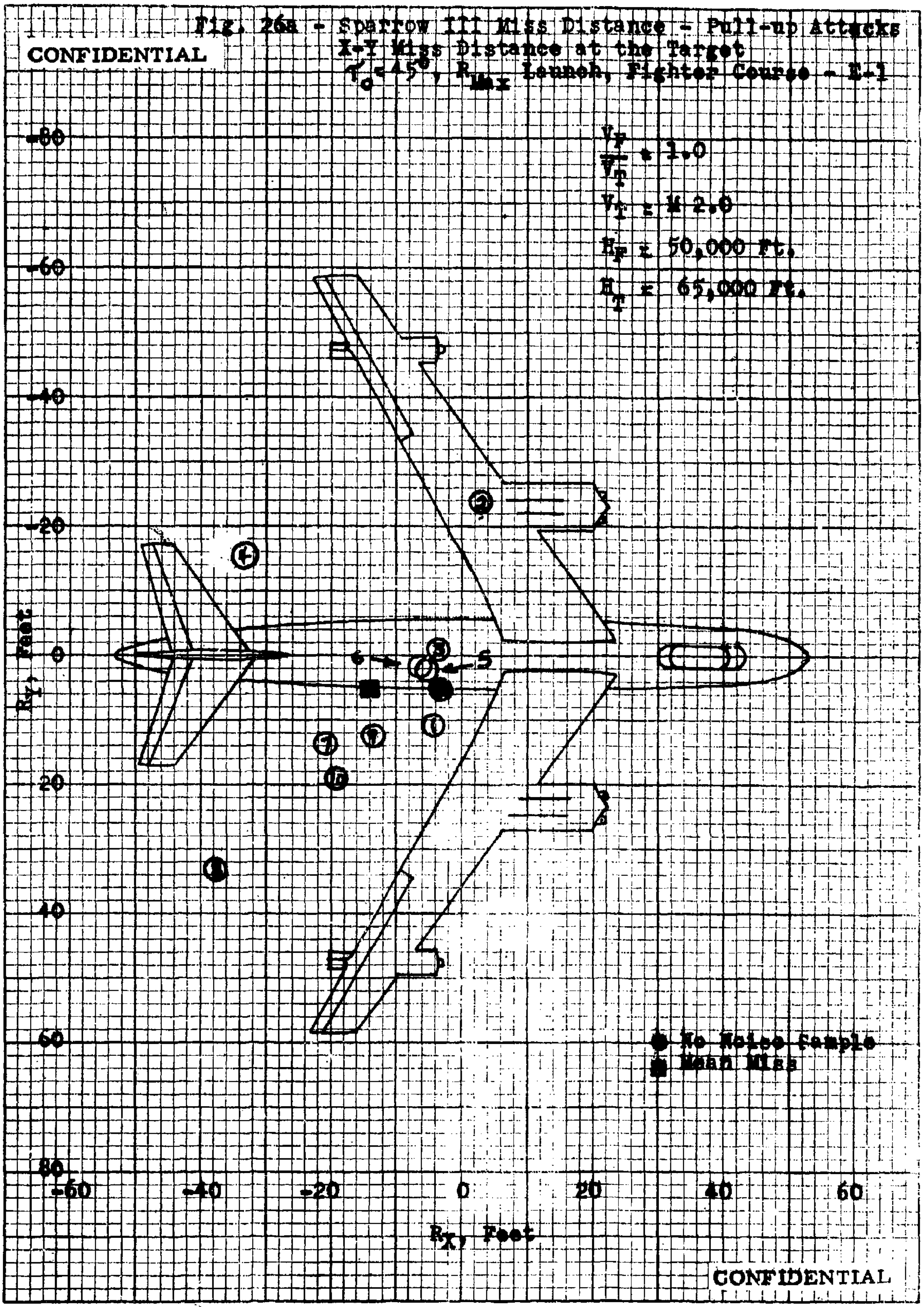

Fig. 26a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\gamma_o = 45°$, R_{Max} Launch, Fighter Course - E-1

Fig. 26b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\gamma_o = 45°$, R_{max} Launch, Fighter Course - E-1

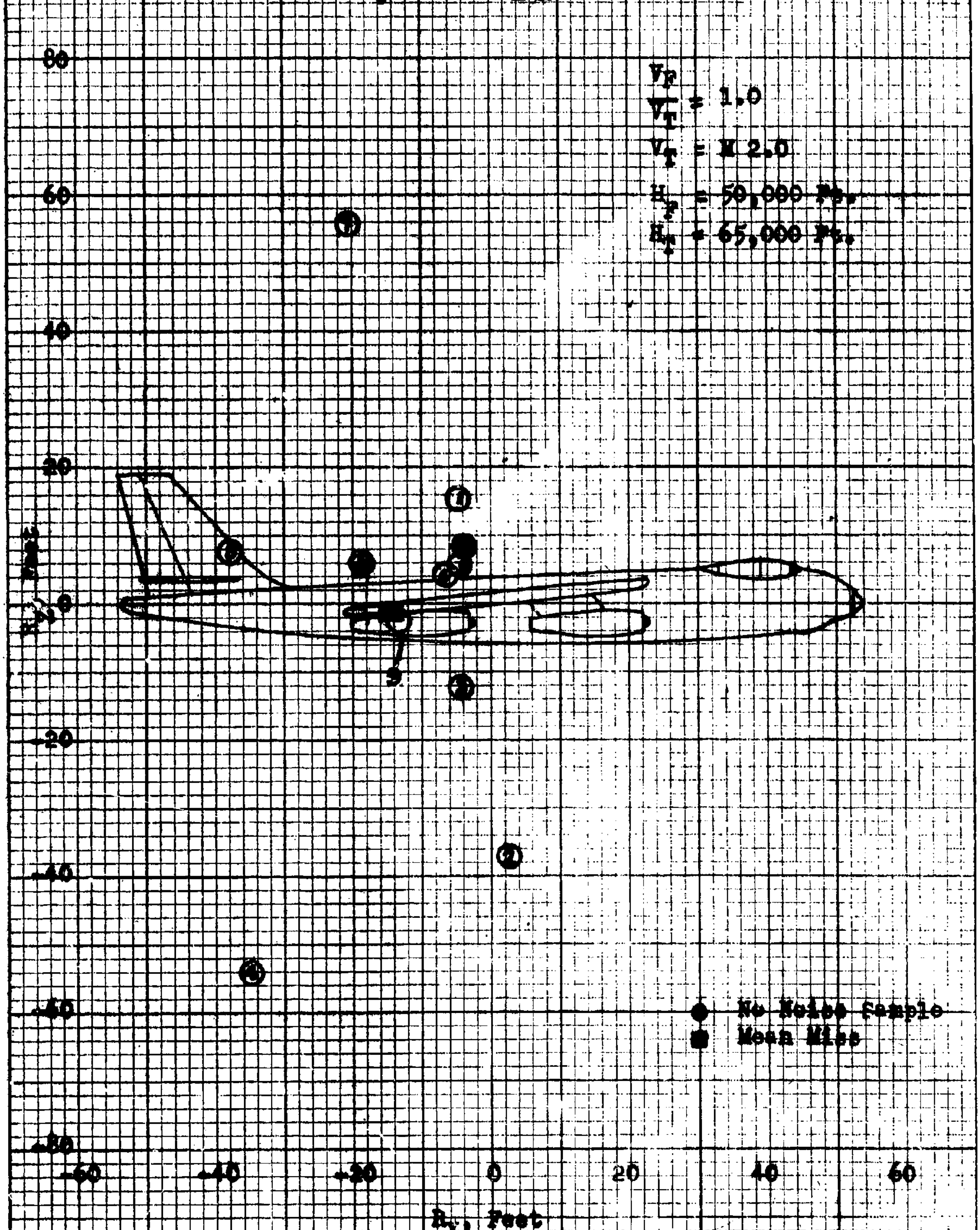

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Fig. 26e - Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\gamma_o = +5^o$, R_{Max} Launch, Fighter Course - E-1

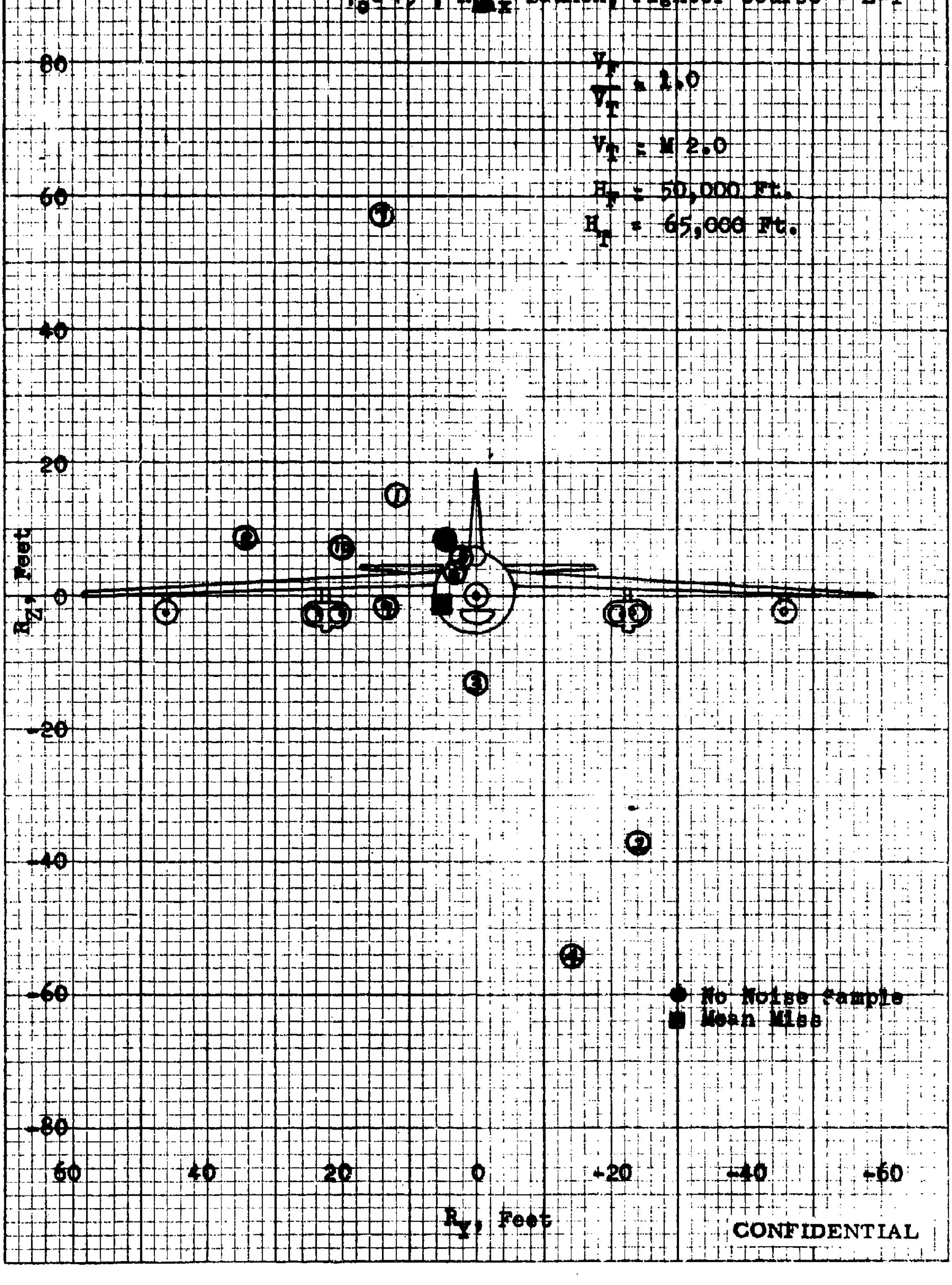

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Fig. 27a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\sigma_o = 45°$, $\frac{1}{2}(R_{max} + R_{min})$ Launch
Fighter Course - E-1

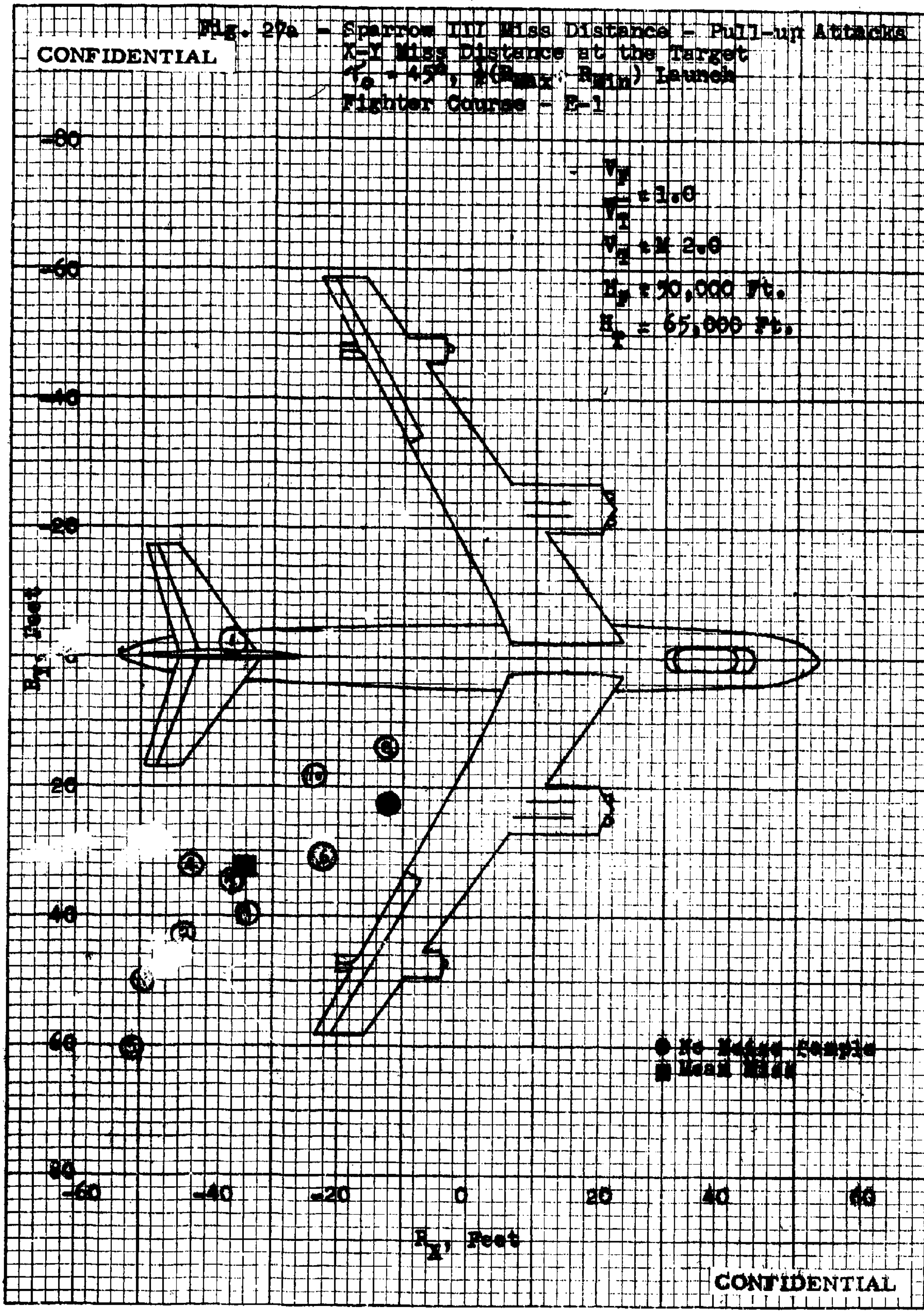
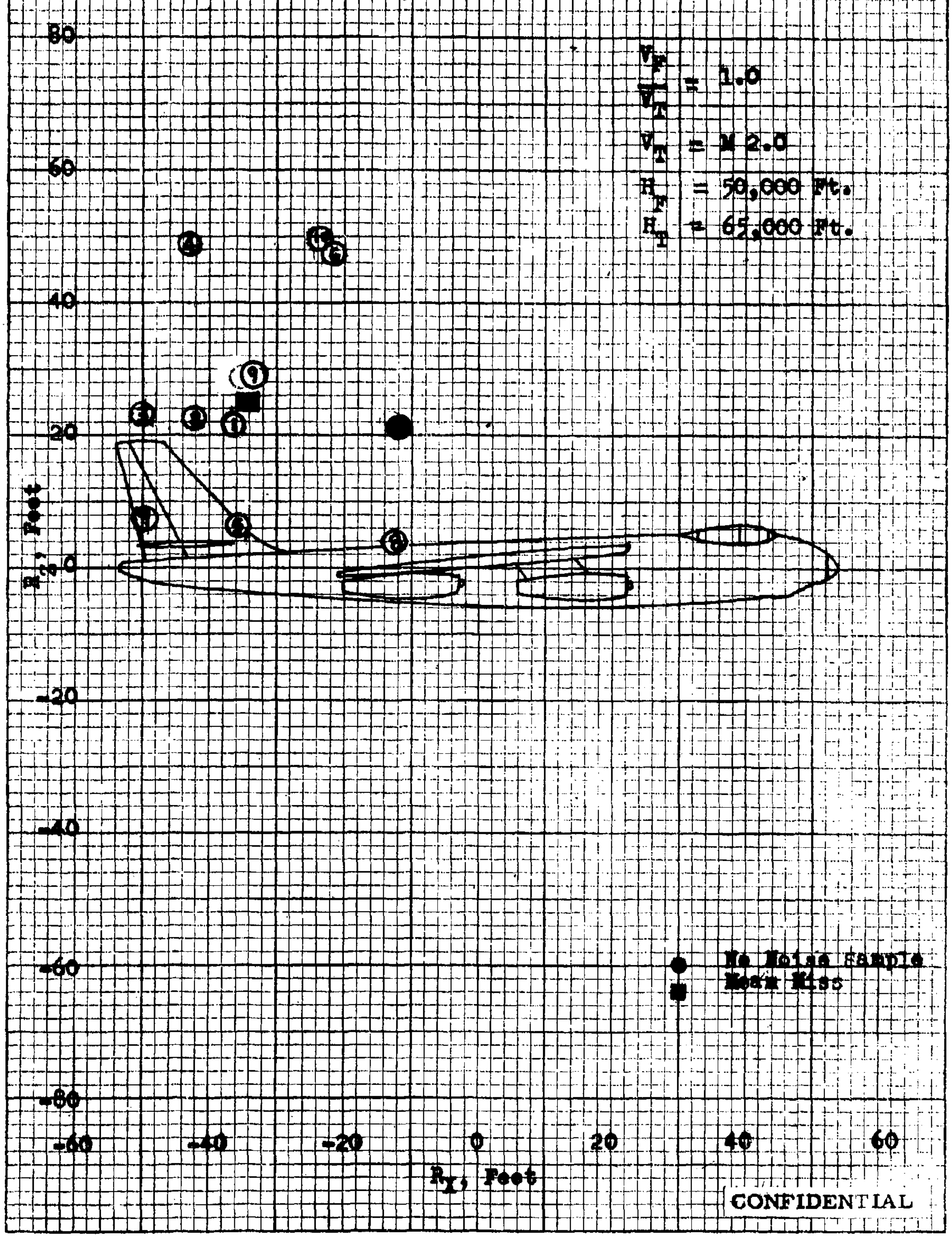


Fig. 27b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\gamma_o = 45°$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch,
Fighter Course - E-1



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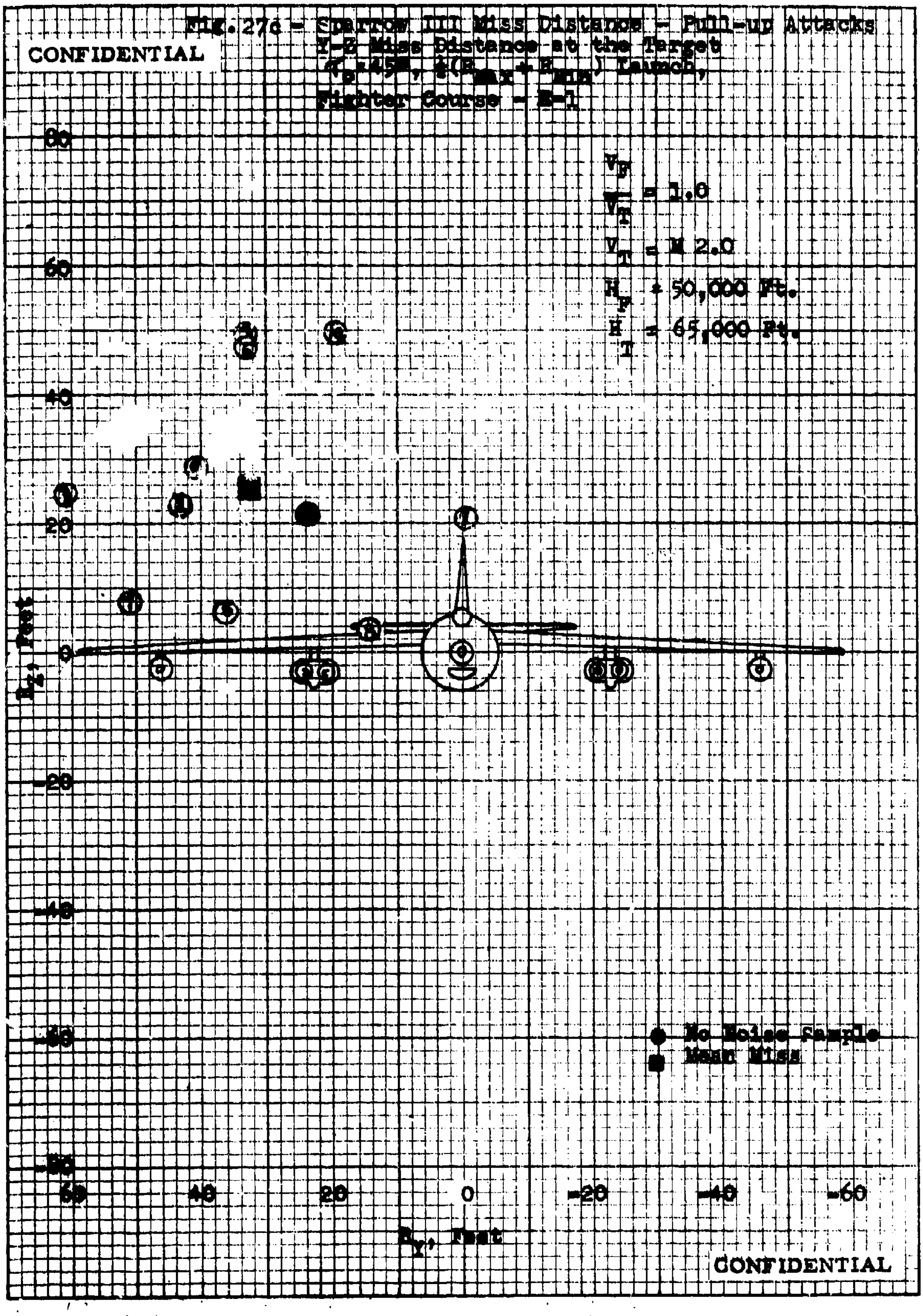

Fig. 27c - Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
($\Gamma_p = 45°$, $\frac{1}{2}(R_{max} + R_{min})$ Launch,
Fighter Course - E-1

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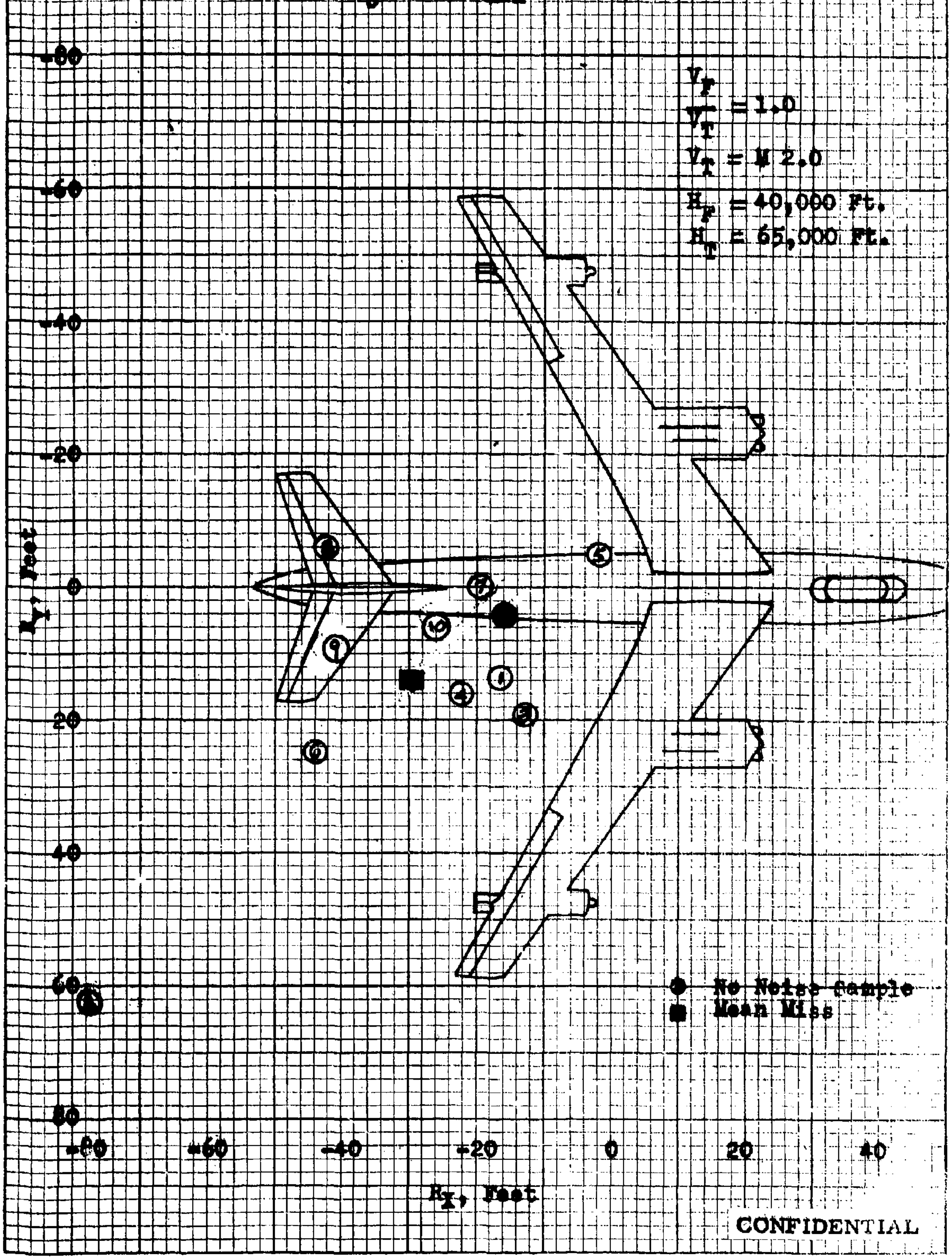
Fig. 28a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\gamma_o = 45°$, R_{max} Launch, Fighter Course - D-1



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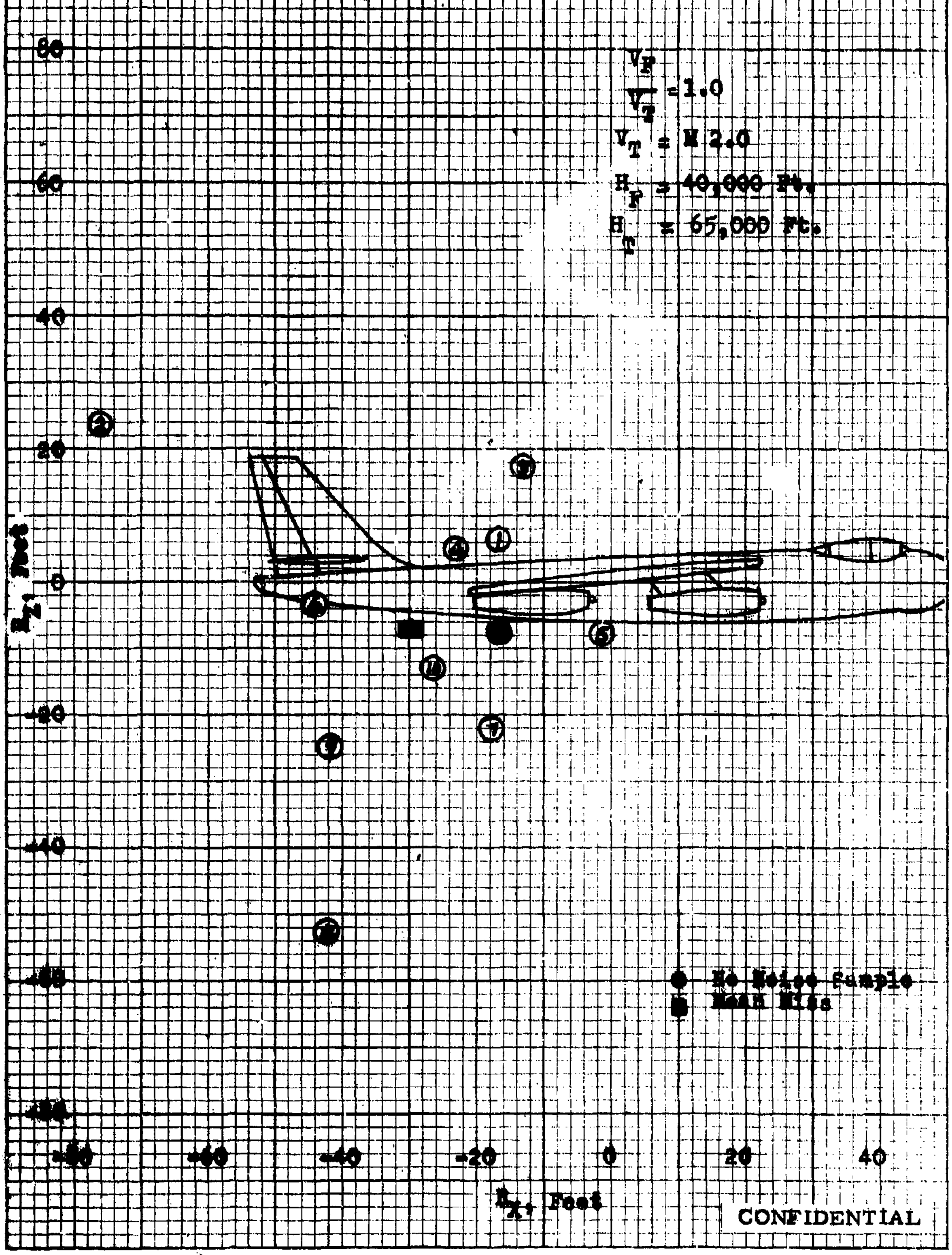

Fig. 28b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\tau_c = 45°$, R_{MAX} Launch, Fighter Course - D-1

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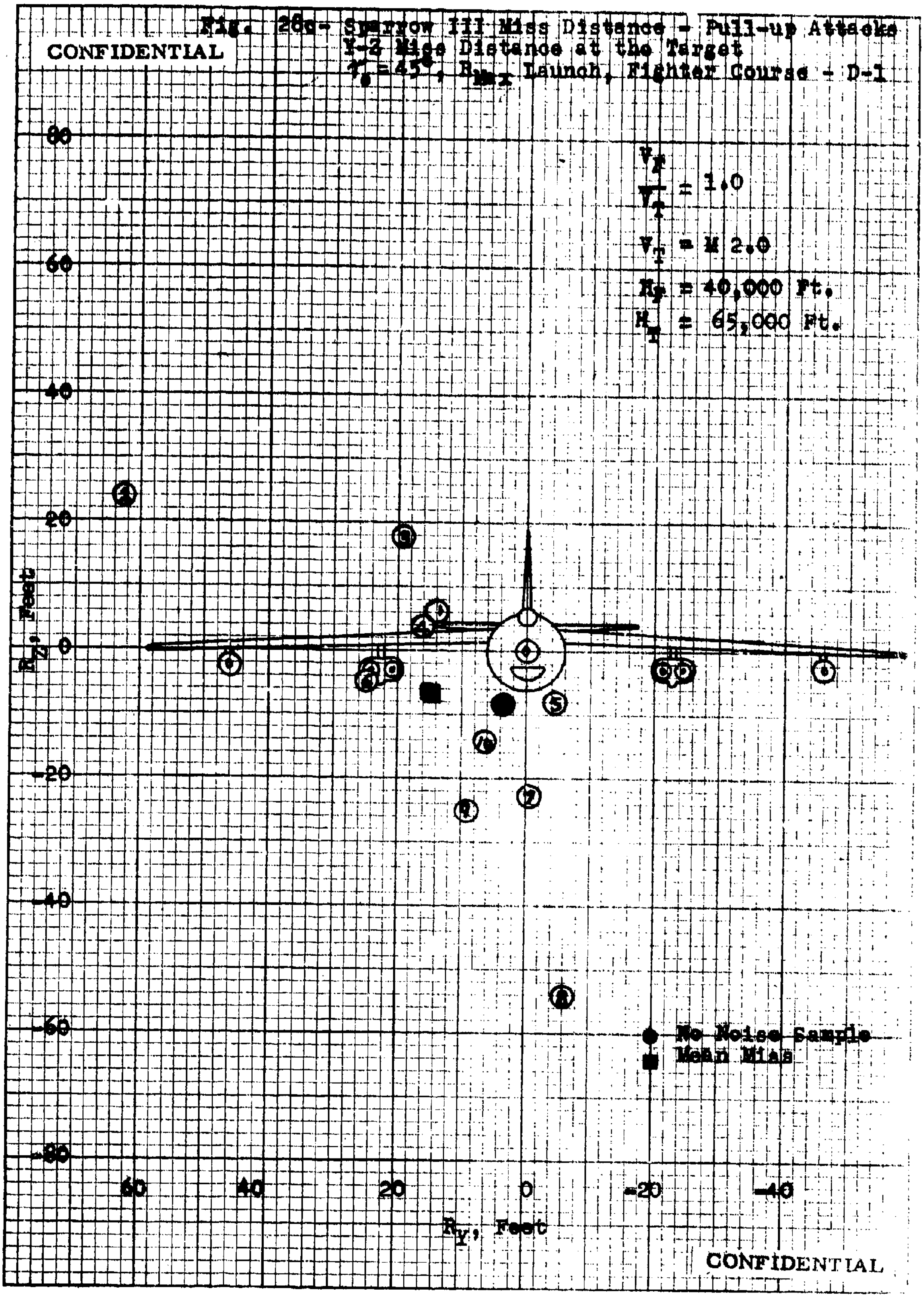

Fig. 26c- Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\gamma_s = 45°$, R_{Max} Launch, Fighter Course - D-1

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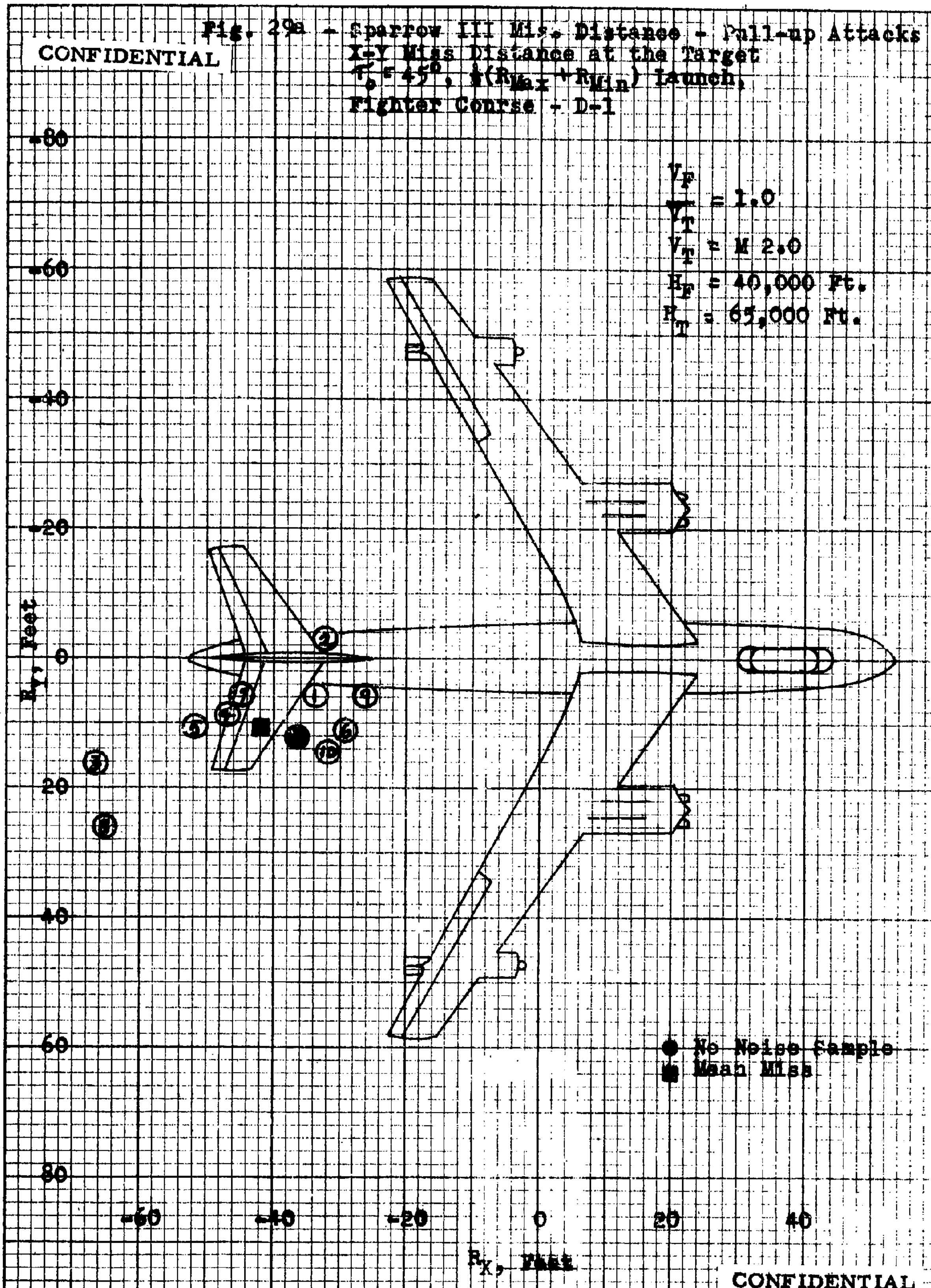
Fig. 29a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\tau_o = 45°$, $\frac{1}{2}(R_{Max} + R_{Min})$ launch,
Fighter Course - D-1



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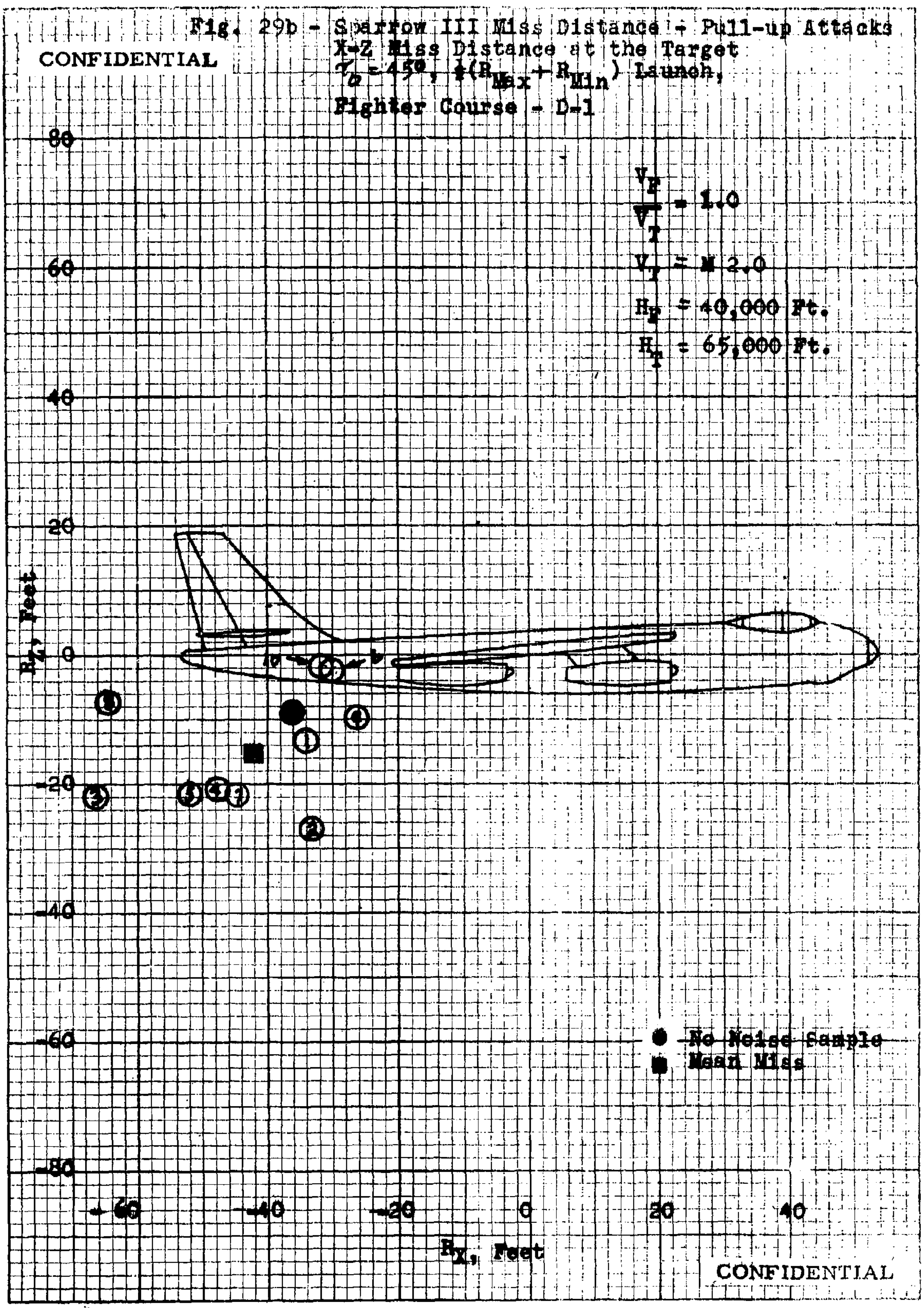

Fig. 29b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\tau_o = 45°$, ½(R_{Max} + R_{Min}) Launch,
Fighter Course - D-1

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Fig. 29c- Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\gamma_0 = 45°$, ½($R_{Max} + R_{Min}$) Launch,
Fighter Course - D-1

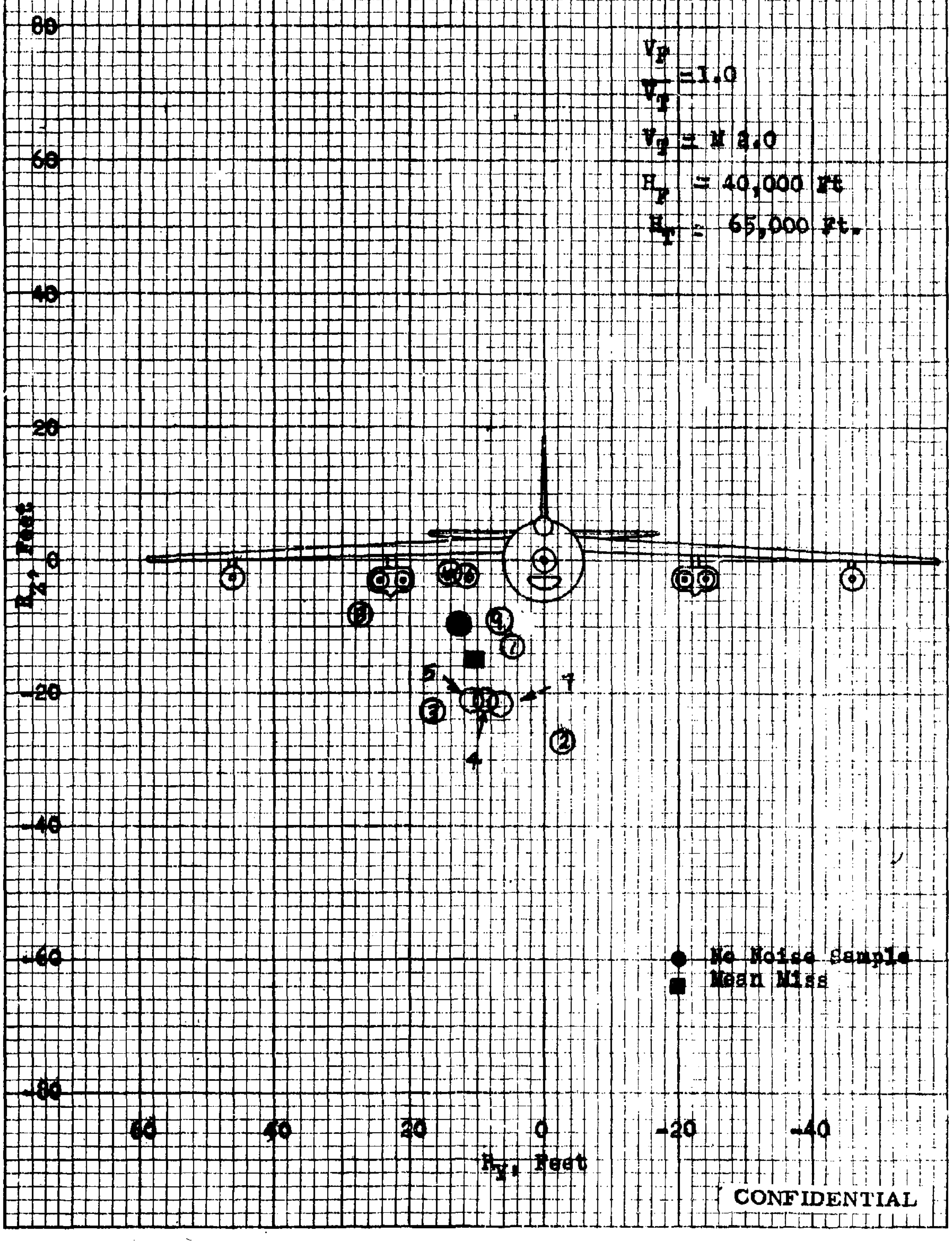

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Fig. 30a- Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$\tau_o = 45°$, R_{Max} Launch, Fighter Course - E-1

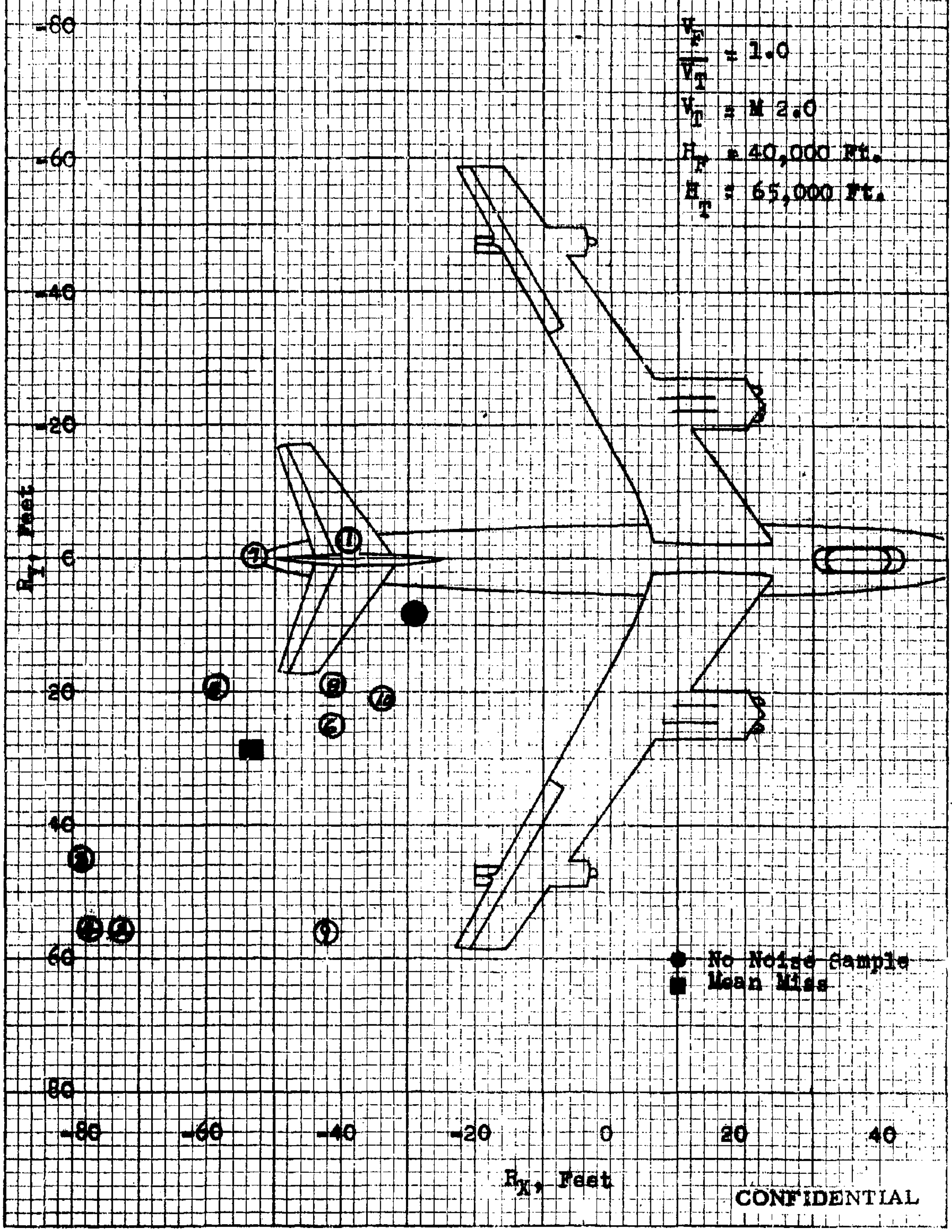

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Fig. 30b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\gamma_0 = 45°$, R_{Max} Launch, Fighter Course - E-1

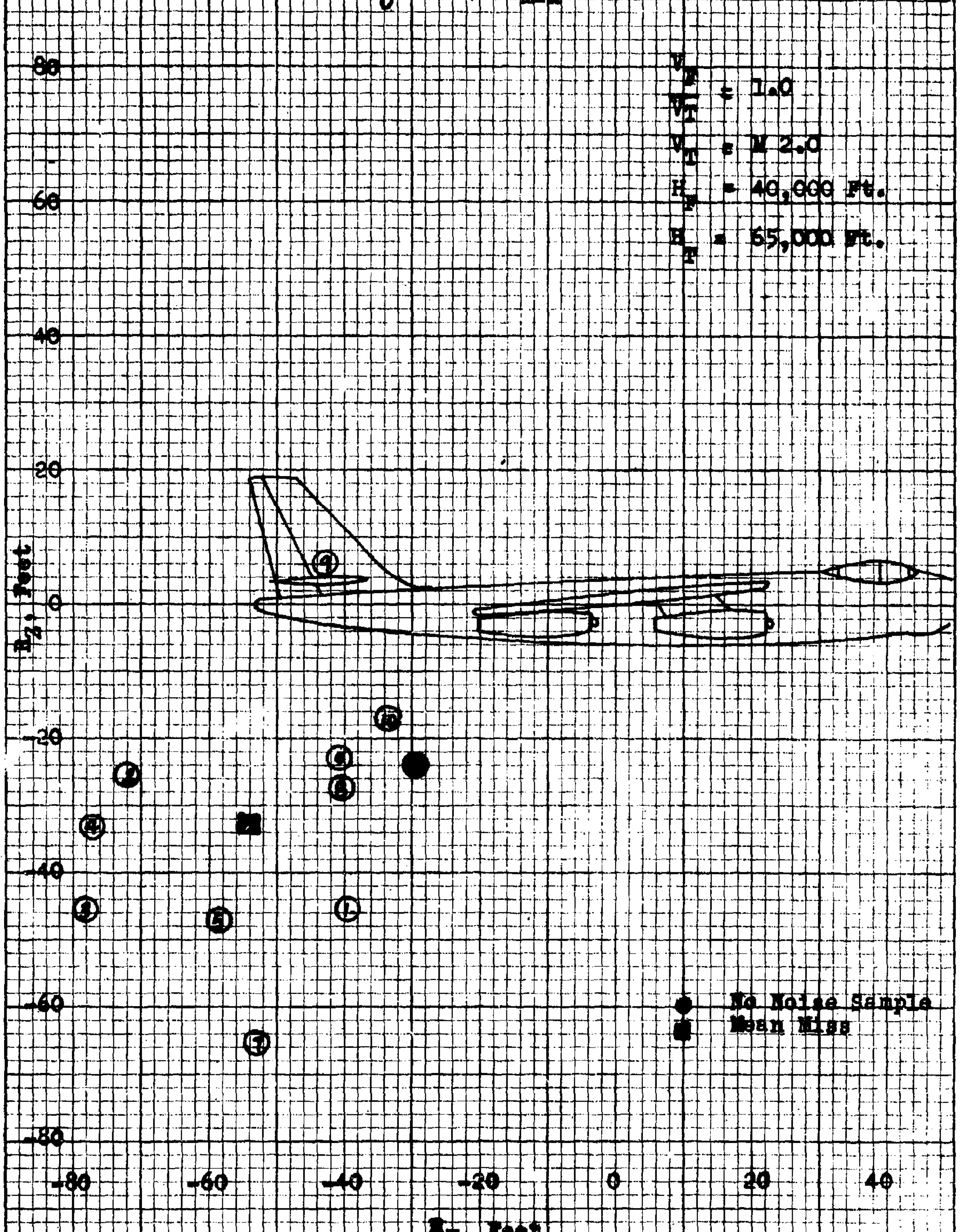

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Fig. 30c - Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\gamma_0 = 45^o$, R_{Max} Launch, Fighter Course - E-1

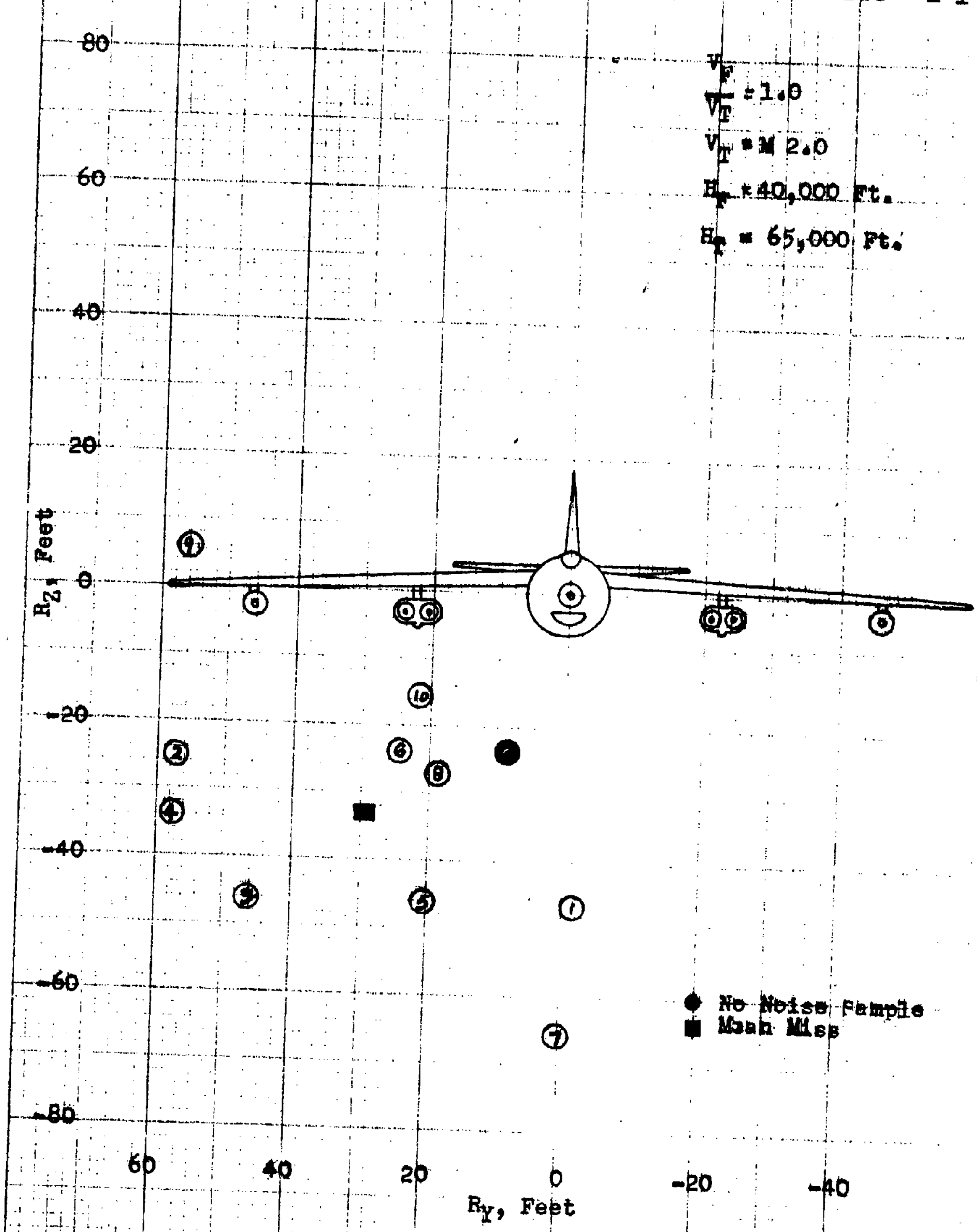

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Fig. 31a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$T_p = 45°$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course - E-1

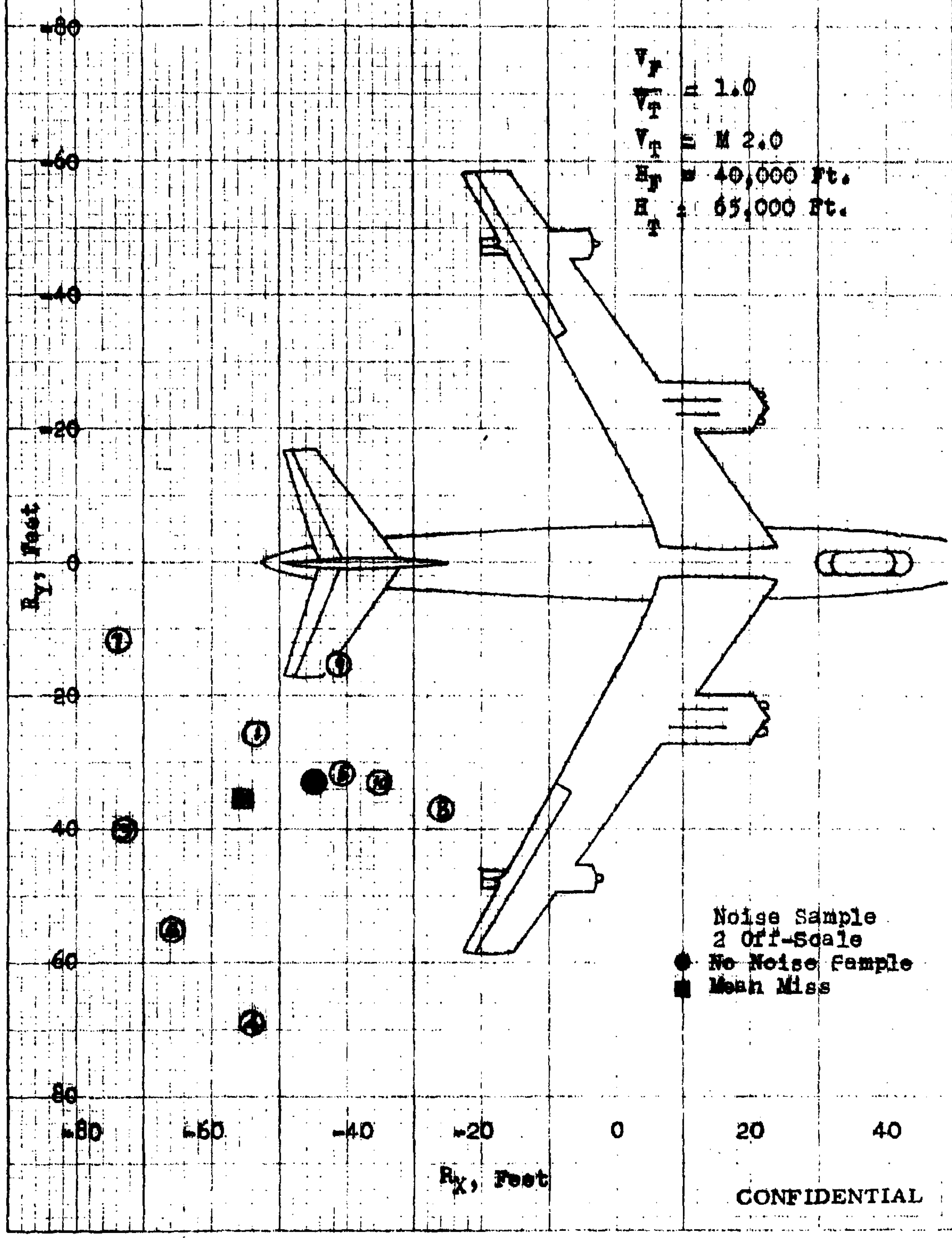

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Fig. 31b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\Gamma_o = 45^\circ$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course - E-1

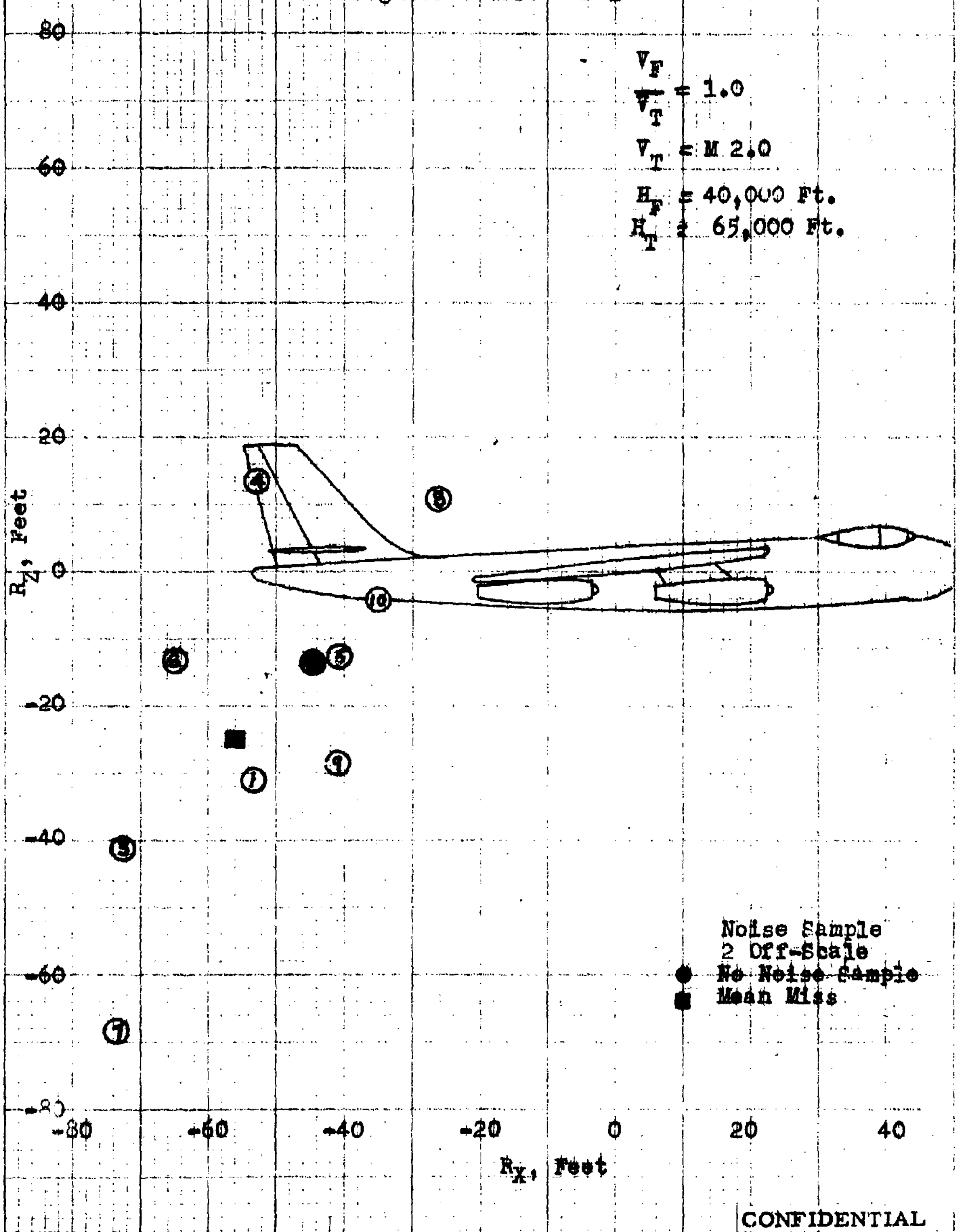

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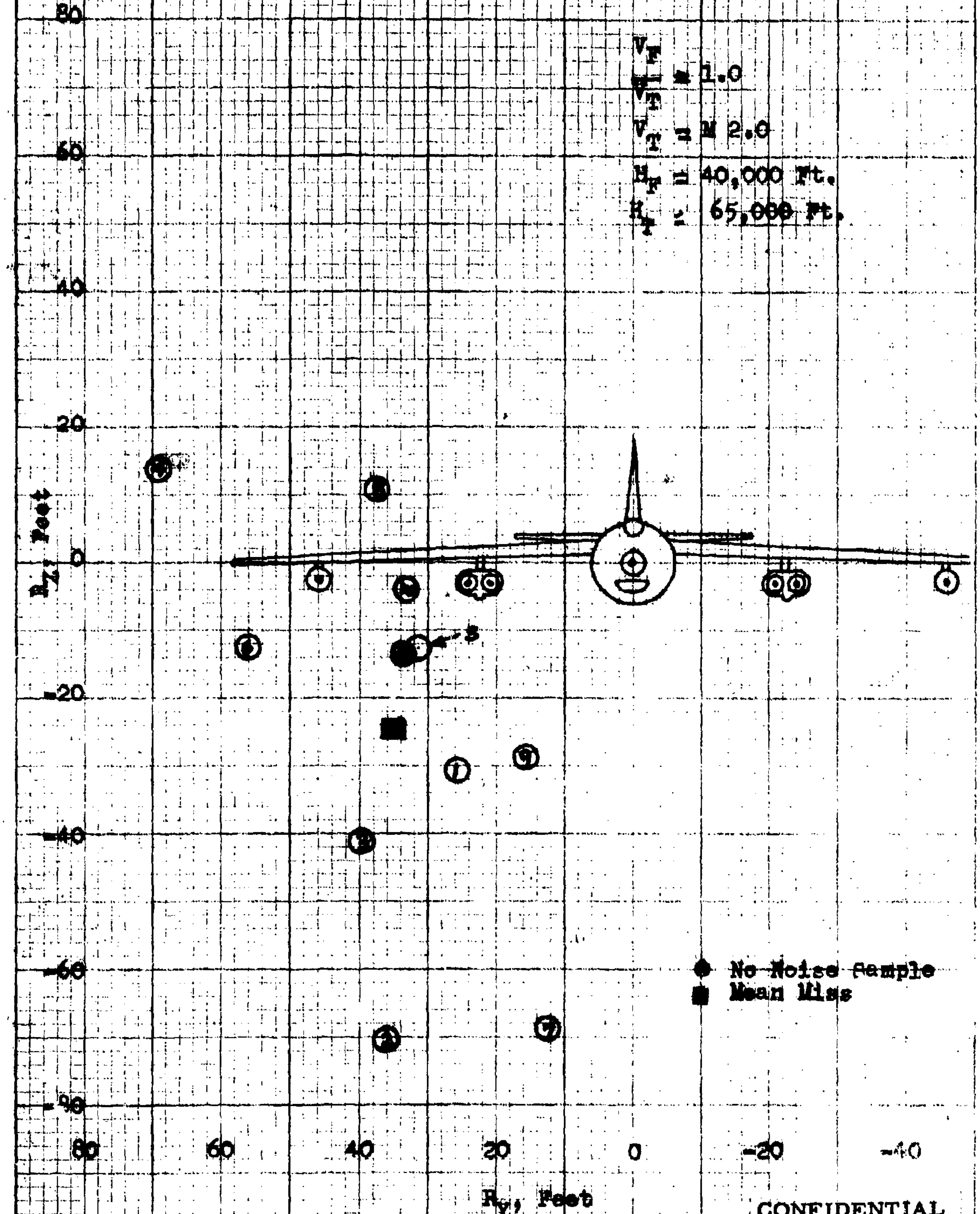
Fig. 31c - Sparrow III Miss Distance - Pull-up Attacks
Y-Z Miss Distance at the Target
$\eta_o = 45°$, $\frac{1}{2}(R_{Max} + R_{Min})$ Launch
Fighter Course - E-1



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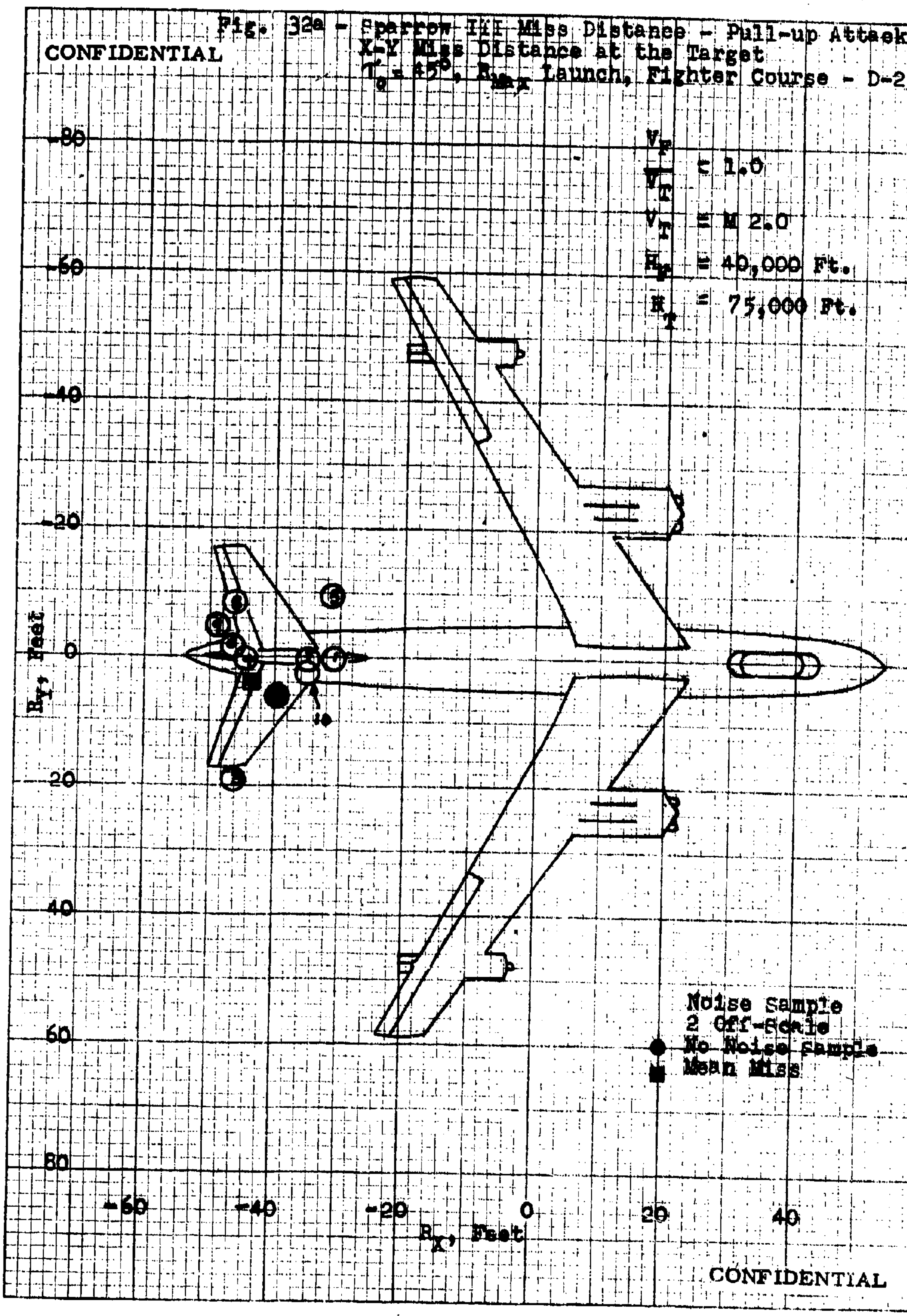

Fig. 32a - Sparrow III Miss Distance - Pull-up Attacks
X-Y Miss Distance at the Target
$T_o = 45°$, R_{max} Launch, Fighter Course - D-2

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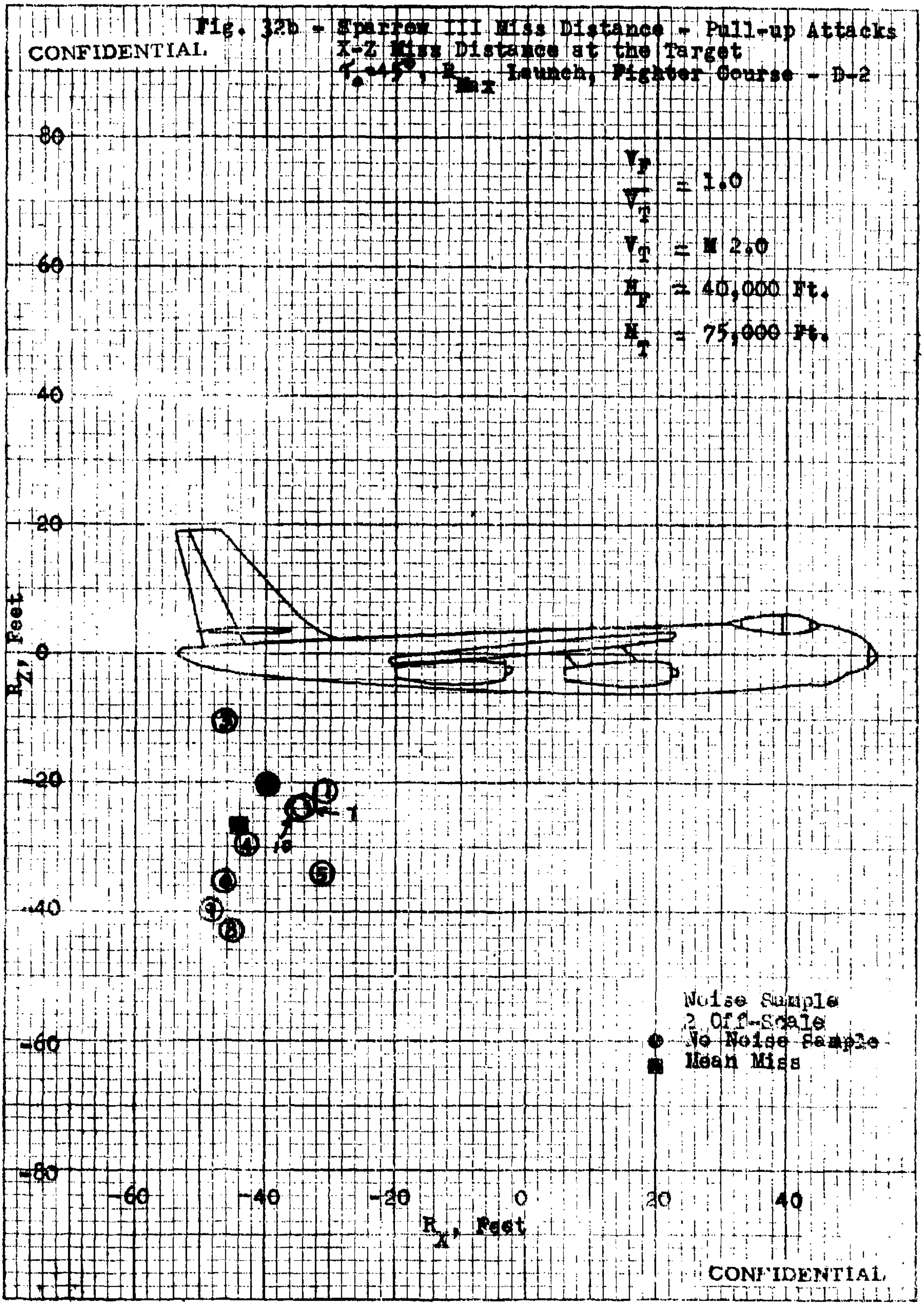
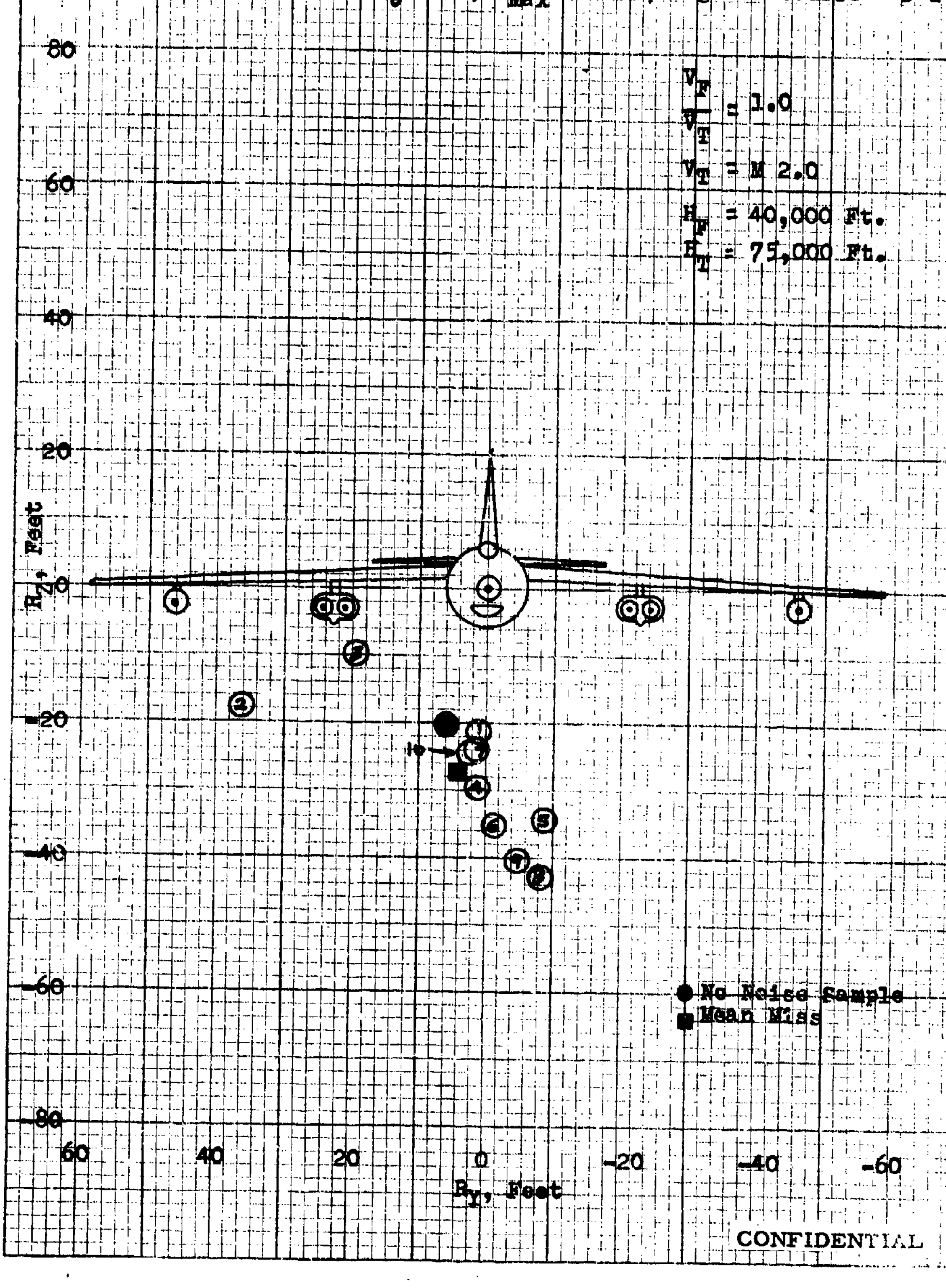


Fig. 32b - Sparrow III Miss Distance - Pull-up Attacks
X-Z Miss Distance at the Target
$\psi_o = 45°$, R_{Max} Launch, Fighter Course - D-2

Fig. 32e – Sparrow III Miss Distance – Pull-up Attacks
Y-Z Miss Distance at the Target
$\gamma_e = 45°$, R_{Max} Launch, Fighter Course – D-2



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CC: Tina Smallwood, Code 1221.1 *ts 3/8/01*

SUBJ: Review of NRL Reports

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- [x] Possible Distribution Statement
- [ ] Possible Change in Classification

Thank you,

Mary Templeman

Mary Templeman
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- [x] Changed to Distribution A (Unlimited)
- [ ] Changed to Classification __________
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AU (10) Ryon ,J. C.
        Loughmiller ,C. M.
        Lister ,R. L.
        Bellavin ,I. N.
        Schmookler,M.
RD (11) Aug 1960
PG (12) 81 Pages
RS (14) NRL-MR-754-Vol-11
RC (20) Unclassified report
NO (21) See also Volume 10, AD-368 352L.
AL (22) Distribution:  DoD only:  others to Director, U. S. Naval Research Lab.,
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